
TORNADO
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CUSTOMER SUPPORT

If you have any questions about Tornado or any of our other products, please contact Customer Support at:

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Surrey, GU15 3AJ

phone 0276 678806 (UK only)
Between 10am and 4pm, Monday to Friday

email address digint@cix.compulink.co.uk

It helps us enormously if you have already returned your registration card but please be prepared to provide the following information:

Name
Address
Product name
Computer
Description of problem and how it occurred
Error messages appearing on screen

CONTENTS

INTRODUCTION

INTRODUCTION

Welcome to **Tornado** - the most comprehensive home computer combat flight simulator to date. Some of you will already know a good deal about aircraft and how to fly them, and some of you will be learning these things for the first time. We have tried hard to cater for both types of user and to design a product of considerable entertainment and educational value. Do not be overwhelmed by the huge manual. This is an immense product. Options range from no-nonsense Quickstart to the multi-aircraft multi-mission campaigns, with exercises in the simulator to prepare you for a range of combat options unsurpassed by any other product. It is only possible to begin to appreciate the depth of **Tornado** after several hours of intensive use. We expect you to continue to discover new aspects of the product for months.

Everybody, regardless of experience level, should start by looking at the separate Technical Supplement. This gives details of how to install the software, and describes any differences between the version supplied for your machine and the PC-compatible version upon which this manual is based.

Tornado is a remarkably complete simulation of the Panavia Tornado GR.4 Interdictor / Strike (IDS) and F.3 Air Defence Variant (ADV) aircraft. The GR4 will be the upgraded RAF version of the Tornado IDS currently flown by the RAF, the German, Italian and Saudi Arabian air forces. If you followed the air war in the Persian Gulf, you will know that this was the aircraft given the job of keeping the Iraqi air force on the ground by destroying its airfields. Its purpose in life is to penetrate deep into enemy territory by flying as low as possible, as fast as possible, and deliver even the dumbest of 'dumb' bombs with pinpoint accuracy. It can do all these things even at night, in thick fog. At low level, in the environment it was designed for, it is the fastest aircraft in the world.

The Tornado ADV is in service with the RAF and Saudi Arabia. It is a modified version of the same airframe, equipped to serve as a long-range, long-

endurance two-seat interceptor. It has a more powerful radar optimised for air-to-air fighting, and carries medium-range radar-guided missiles. As the name Air Defence Variant suggests, its intended role is to defend rather than attack, and it is normally expected to do this by shooting down enemy bombers. It shares the all-weather capability of the IDS version, but unlike the IDS it cannot terrain-follow.

This level of performance demands a very sophisticated aircraft. Even with a crew of two, there is so much to do, and the situation can change so fast that most of the time the aircraft is flown by an extremely smart autopilot. You are about to step into the shoes of two very hard-working aircrew. But even if this is the first flight simulator you have ever bought, do not despair. You do not have to do it all at once, and we provide flight training from absolute beginner level if you need it.

Simulating such a complex aircraft was not easy. It involved a phenomenal amount of research and design but the degree of authenticity achieved would not have been possible without the assistance of the Royal Air Force and British Aerospace. We have done everything we can to provide a detailed and accurate simulation of the aircraft's systems and flying qualities, with the invaluable help of many RAF Tornado aircrew. We have also provided a level of visual realism, density and detail which breaks new ground for a home computer simulation, but even this is only half the story.

Precise automatic navigation demands precise and detailed flight planning, and our mission planning system is in many ways far in advance of the one the RAF uses at present. This is no reflection upon the people and organisations who developed the system in use - we have the advantage of nearly ten years of explosive technological progress since that system was designed.

Within the last few months of **Tornado's** development, the UK Ministry of Defence has issued a development contract for a new mission planning system, to be used for the Harrier GR.7 and potentially the Tornado GR.4. It is called AMPA (Advanced Mission Planning Aid), due to be in service by early 1995, and the published description (in Flight International, 20 January 1993)

sounds eerily familiar to those of us who specified and developed **Tornado**'s mission planning system. There is no question of one being a copy of the other - we simply came to very similar conclusions about what is possible and desirable to do with the available computer power. But **you** don't have to wait until 1995!

We never intended or presumed that this project would attract serious attention from the people who get to fly the real thing or from the aerospace industry, so we were highly gratified when it did. This same product is now under consideration for professional ground-based training applications and we are delighted that our efforts are being recognised outside the entertainment market.

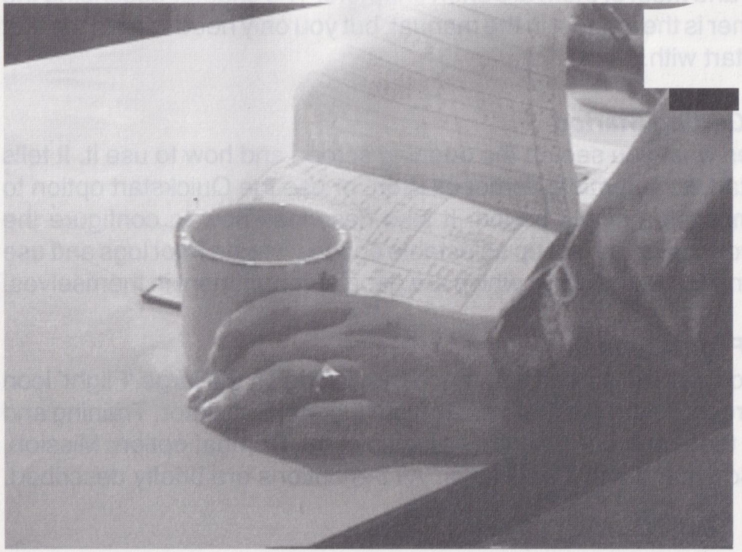
Unlike any of our previous simulations, **Tornado** is designed to be the first of many new leading-edge products. We haven't succeeded in putting in everything that we wanted to - no shortage of ideas - just time. These vast projects involve an unbelievable investment in man power and equipment and sooner or (usually) later, we have to get the product published in order to fund the next one. But we do what we enjoy most and we hope it shows.

Thank you for purchasing **Tornado** - we hope you enjoy it.

The Tornado team

FINDING YOUR WAY AROUND THE MANUAL

CHAPTER 1



FINDING YOUR WAY AROUND THE MANUAL

All users should check their Technical Supplement to find out how to install and start this software.

This chapter covers two main topics: one is the 'Front-end' of the program, which among many other things lets you create logs, select missions and plan them; the other is the aircraft, how to fly it, how the weapons work and how to use them.

Chapters about the 'Front-end'

Chapters 2 to 6 are the ones which describe the 'Front-end'. Everyone needs to read them, and most of them are short chapters. The chapter describing the Mission Planner is the longest in the manual, but you only need to read the first third of it to start with.

Chapter 2 - Getting Started
This describes what you see on the opening screen and how to use it. It tells you how to start an automatic demonstration, or use the Quickstart option to leap into combat at a single bound. It also describes how to configure the software for your machine, set up selectable options, create Pilot logs and use the Explore and Review modes, which are good entertainment in themselves.

Chapter 3 - Flight Options
This chapter covers the screen you reach by clicking on the large 'Flight' icon on the first screen. There are three basic flight modes: Simulator, Training and Combat; and there are four different varieties of the Combat option: Mission, Campaign, Command and Two-Player. All the options are briefly described.

Chapter 4 - Mission Selection Screen
This is where you make your choice about what you are going to do within the Flight or Combat option you selected, and (for the Combat options), which of the three possible War Zones you are going to fly over.

Chapter 5 - Mission Planner
This is a monster of a chapter because the Mission Planner is a very powerful and sophisticated piece of software. The chapter is divided into three self-contained sections, and the user who just wants to fly preset missions for the moment can get all that is required from the first of these.

Chapter 6 - Debriefing
This brief chapter covers the report you see at the end of each flight, and what to do about it if you don't like it.

Chapters about the Aircraft and Weapons

These are mainly long chapters covering many topics - if you are new to the subject there is a lot to learn. Experienced pilots can do a good deal of skipping, and try to pick up what they need by using the Aircrew Notes in conjunction with the Index.

Chapter 7 - Elementary Flying Training
This chapter is mainly for the benefit of users who know nothing about aircraft or flying, including those who have never had to worry about stalling or overspeeding before. If the aircraft refuses to fly or keeps shaking itself to pieces around you and you cannot work out what is going on, grit your teeth, swallow your pride and start here. This chapter also covers automatic landings and taking off.

Chapter 8 - Advanced Flying Training
Large parts of this chapter build on the previous one to take a novice up to a level where he or she can manoeuvre the aircraft freely, set up an approach and land with a minimum of automatic help. Some of the very powerful

navigation systems and avionics of the Tornado are also described, and the chapter concludes with a section on emergencies, including the spin recovery drill.

Chapter 9 - External Views

This very short chapter describes the rich and flexible options for out-of-aircraft views of yourself and others.

Chapter 10 - Weapons Conversion

This chapter should be required reading for everyone, though real Tornado pilots will be able to skim through it. They will find a few omissions and simplifications of the systems they know - most other users will be faced with concepts and weapons they may never even have heard of before. You will never be truly effective until you can use all the possible weapons in all the possible modes, and you will not be able to do that unless you know this material, one way or another.

Chapter 11 - Aircrew Notes

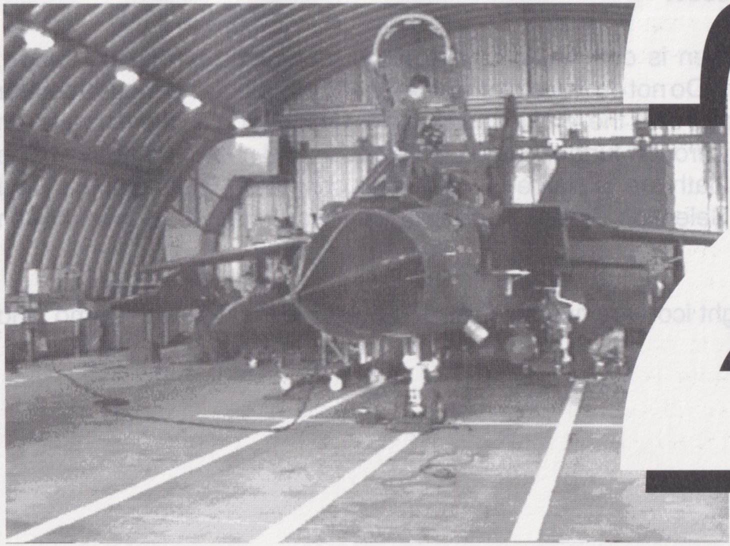
This is a summary description of the aircraft instruments and avionics. A very experienced user may be able to get most of what he or she needs to know from this chapter in conjunction with the Control Summary card, using the Index to find detailed descriptions where more explanation is wanted. Once you know roughly what is available, you can use this chapter for quick reference.

Chapter 12 - Reference

This gives drawings and basic data on aircraft, vehicles and weapons appearing in Tornado. Know your enemy - and your allies. We should add the disclaimer that we are not trying to re-fight the Cold War; we chose CIS equipment for the 'orange' forces because most of these systems correspond neatly, one-to-one, with 'blue's' Western equipment. As far as we are aware, all the CIS equipment which features in Tornado is being actively marketed to the world at large, so 'orange' could be almost anybody. Just add your favourite dictator and stir.

GETTING STARTED

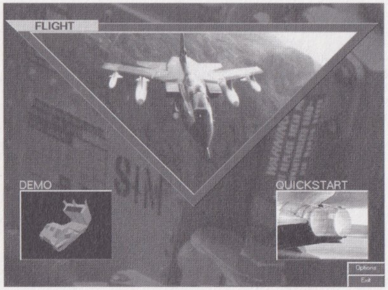
CHAPTER 2



GETTING STARTED

THE MAIN SCREEN

All users should consult the separate Technical Supplement for details of how to install and run Tornado on their particular type of computer. If you find differences between what is described in this manual and what appears on your screen, check with the Technical Supplement. Once you have started the program and the title sequence has finished, you should find yourself looking at the Main Screen. the 'Front End' of Tornado. The overall structure of the program is shown opposite in *diagram 2.1*.

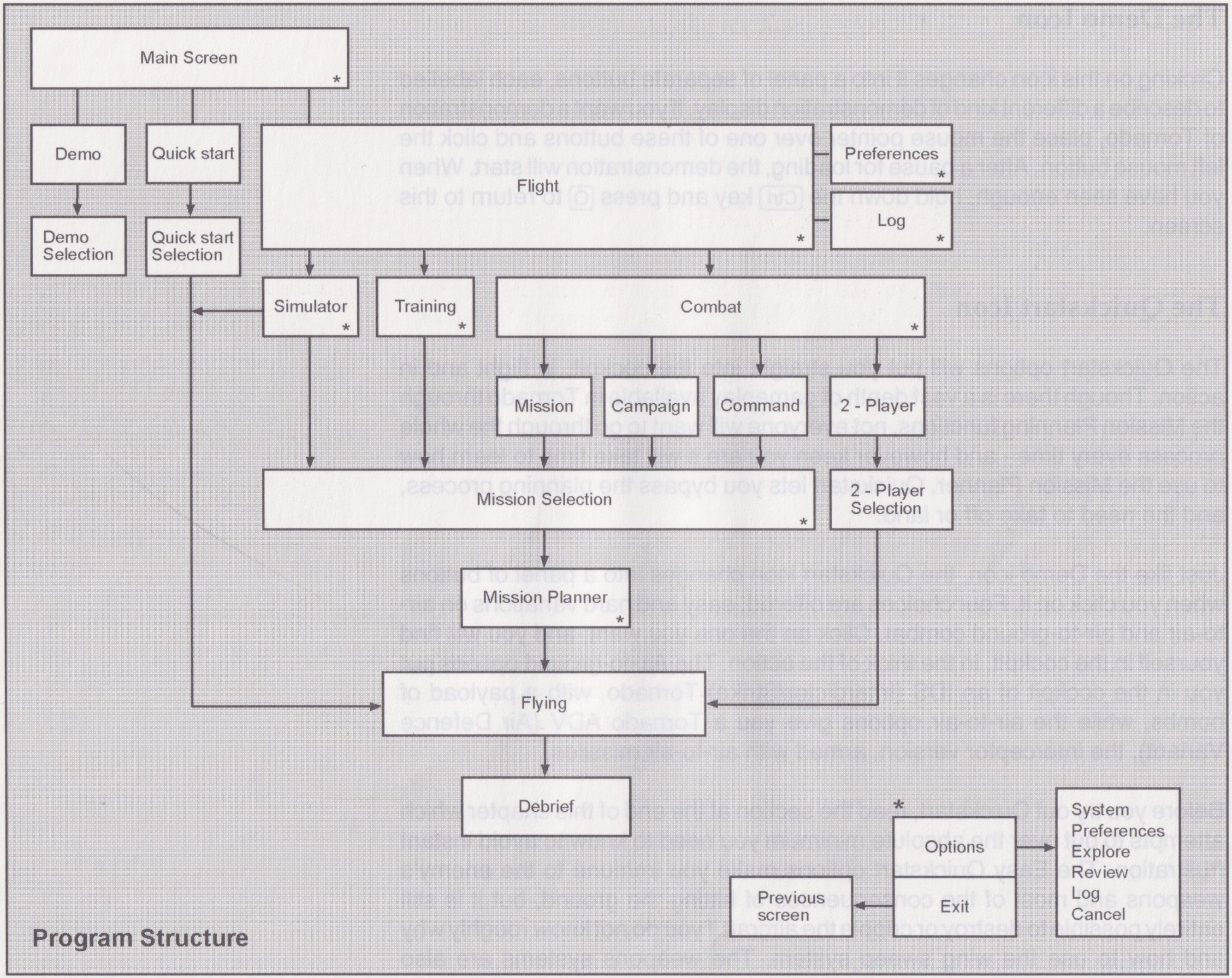


Main Screen

The Flight Icon

The Main Screen is dominated by the large triangular icon in the centre, labelled 'Flight'. Do not do this straight away, but if you place the mouse pointer over this icon and click the left mouse button it will start you on the normal path to the aircraft, through further stages of selection and mission planning. The stages in this path are explained in two short chapters; 'Flight Options' and 'The Mission Selection Screen'; and one very long chapter on the Mission Planner.

Below the Flight icon are two smaller rectangular icons labelled 'Demo' and 'Quickstart'.



Program Structure

diagram 2.1

The Demo Icon

Clicking on this icon changes it into a panel of separate buttons, each labelled to describe a different kind of demonstration display. If you want a demonstration of Tornado, place the mouse pointer over one of these buttons and click the left mouse button. After a pause for loading, the demonstration will start. When you have seen enough, hold down the Ctrl key and press Q to return to this screen.

The Quickstart Icon

The Quickstart options will put you straight into the cockpit, in flight and in action. Though there is a vast depth of gameplay available in Tornado through the Mission Planning functions, not everyone will want to go through the whole process every time - and however keen you are it will take time to learn how to use the Mission Planner. Quickstart lets you bypass the planning process, and the need to take off or land.

Just like the Demo icon, the Quickstart icon changes into a panel of buttons when you click on it. Four choices are offered, easy and hard variations on air-to-air and air-to-ground combat. Click on the one you want, and you will find yourself in the cockpit, in the thick of the action. The Air-to-ground options put you in the cockpit of an IDS (Interdictor/Strike) Tornado, with a payload of bombs, while the air-to-air options give you a Tornado ADV (Air Defence Variant), the interceptor version, armed with air-to-air missiles.

Before you try out Quickstart, read the section at the end of this chapter which attempts to put over the absolute minimum you need to know to avoid instant frustration. The Easy Quickstart options make you immune to the enemy's weapons and most of the consequences of hitting the ground, but it is still entirely possible to destroy or cripple the aircraft if you do not know roughly why and how to use the wing sweep system. The weapons systems are also realistic, and do not have the magical properties you may have come to expect. If you want hits, you are going to have to work for them.

THE TORNADO USER INTERFACE

Most computer users should be able to handle our point-and-click system at a glance, but we do use a few novel conventions we have invented for our own purposes. Here we will try to explain how the system works from absolute basics upwards. Experienced users should bear with us - some of this will be new to them as well.

Pointing and Clicking

The front-end of the Tornado system (that is, everything outside the cockpit of the aircraft), is designed to be controlled exclusively by your mouse. The only time you will need to use the keyboard is to type in names when creating Pilot logs. To activate a function, you just move the mouse over your desk to place the mouse pointer symbol on the screen (a small upright cross) over an icon or a button (both are defined below), and click the left button on the mouse. The right mouse button is only used to move about and change zoom levels on the Mission Planner Map.

Icons and Buttons

Icons are picture-symbols with borders around them, like the Flight, Demo and Quickstart symbols on the Main Screen. Buttons are small outlined panels with text in them, like the rectangles marked 'Options...' and 'Exit' in the lower right corner of the screen.

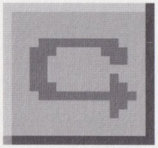
Sometimes clicking on an icon or a button will cause an immediate action, sometimes the icon will subdivide into smaller icons (or buttons) to offer you more choices, and sometimes it will call up a window (see below), which may display text and/or contain still more buttons.

Many buttons will change colour when you click on them, to indicate that the function or option they control is selected (switched on). Sometimes you will see a row or column of buttons, only one of which may be selected at a time - these are often called 'radio buttons'. Most of the time the text on the buttons should tell you what they mean and what they do. If it is not obvious, check with this manual. If a button disappears after you make a selection, it is because that button's function is now irrelevant or inappropriate.

There are two special types of button which are peculiar to Tornado; the Cycle button and the Figure button.

Cycle buttons

A Cycle button is a space-saving substitute for a bank of 'radio buttons'. It is a small square button with a circle/arrow symbol in it, always placed to the left of a short text panel describing an option or a state. Clicking on the Cycle button changes the text, selecting a different option or state. Up to four different options may be selectable by clicking repeatedly on a Cycle button.



Cycle Button

The first Cycle button you are likely to encounter is the one on the Preferences screen (see below).

Figure buttons

Figure buttons are provided where you need precise control over a figure (usually a time, a speed or an altitude). The digits of the figure, sometimes grouped together, will be outlined to mark them as buttons. To change the figure, click on the button showing the digit(s) you are interested in. This will cause two further buttons to appear, marked with arrows, one above and one below the digit(s). Click on the arrow buttons to change the figure up or down by one; click and hold down the mouse button for rapid change.

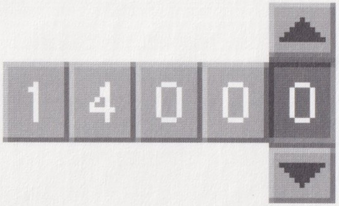


Figure Buttons

When you change a digit up past 9 or down past 0 the next digit up will also change up or down, even though it is not selected. You can instantly select another digit to change by clicking on it, or dismiss the arrow buttons by clicking again on the selected digit itself.

Windows
These are independent superimposed panels (like small inset screens within the larger screen) showing text, or groups of related buttons, or both. Each has a specific purpose. You will find most of them in the Mission Planner, though they do occur elsewhere. All the windows you will see in Tornado have a Title Bar, which should usually explain what they are for. Any window may be moved (dragged) anywhere on the screen by clicking in the Title Bar and holding down the mouse button. Moving the mouse will then drag an outline of the window across the screen. When it is in the place where you want it, release the mouse button and the window will be redrawn in its new position.

Most windows also have a Close box. This is found at the left-hand end of the Title Bar. Clicking in the Close box will close the window, causing it to disappear. Some windows do not have a Close box, either because there is no reason for closing them or because they are telling you something it would be unwise to ignore, like the Problems window in the Mission Planner which tells you when your flightplan is risky or outright suicidal.

Windows can lie on top of one another, partly or totally overlapping. If the one you want is behind another, just click in the Title Bar of the window you are interested in to put it in front. On the PC version at least, you can choose whether the windows themselves are opaque or semi-transparent (see the Preferences option below).

OPTIONS.../EXIT BUTTONS

In the bottom right corner of all screens (except when flying, exploring or going through a recognition review) is a pair of buttons, marked 'Exit' and 'Options...'. If you click on 'Exit', you will go back to the previous screen, or if you are on the main screen (the first screen), you will be asked if you want to quit the program. Whenever this button is shown, the option is always available, and you can use it without incurring penalties.

The upper of the two buttons, marked 'Options...', works in a different way. If you click on this and hold down the mouse button, it will expand into a menu showing the following options:

System	Allows you to quit the program immediately
Preferences	For fine-tuning the program for your equipment
Explore	Lets you explore any map as a disembodied eye
Review	Shows all military aircraft and fighting vehicles
Log	For creating, selecting or reviewing Pilot Logs
Cancel	Does nothing - the safe option!

When the menu first appears, the 'Cancel' item is under the mouse pointer. Keep holding the mouse button down and move the pointer up and down over the menu. You will see that each item is highlighted in turn as the pointer moves over it. Move the pointer back down over 'Cancel' and release the button. The menu collapses back into the 'Options' button, and nothing else happens - which is just what the 'Cancel' option is supposed to do - nothing.

All the items in this menu work the same way; click on 'Options...' and hold down the button, move the pointer till the item you want is highlighted, and then release the button.

The 'System' and 'Cancel' options do not really need explaining. The other options are explained in the following sections. Several of these call up screens which themselves contain the 'Options...' and 'Exit' buttons. Clicking on 'Exit' from any of these will return you to the previous screen.

PREFERENCES

This screen allows you to preset various optional features of the simulation, to select sound hardware where appropriate, and to turn the title music on and off. Many of these switches are provided to allow you to cut down on detail and improve speed, if you think that your computer is running too slowly - it takes

a fast machine to run Tornado at a high frame rate if all the options are turned on.

The switches on this screen divide into three groups. One of these groups almost exactly duplicates the switches available in flight using the Kneepad (Look Down) View, and is mainly concerned with setting up the simulation environment. On the Kneepad, you switch options by pressing the number keys on the top row of the keyboard, here you point and click.

Simulation Preferences

Visual Range

In your outside views, nothing will be drawn beyond the selected Visual Range, which is given in miles. Click on a figure to select it.

More ←		DETAIL		→ Less
25	20	15	10	5
Slower ←		SPEED		→ Faster

Ground

This switch will turn on or off most of the groups of trees and the field patterns we have provided to give a true sensation of speed and depth in low-level flight.

More ←	DETAIL	→ Less
Textured		Plain
Slower ←	SPEED	→ Faster

Hills

We chose not to use the currently-fashionable Gouraud shading effect to represent undulating landscape. This looks very good in the distance, but makes it nearly impossible to judge your height above ground by eye because close to the aircraft the shading degenerates into an unstable shifting mass of colour. Instead, when this switch is set to 'Textured', the faces making up our hills will subdivide into smaller counter-shaded faces as you approach them. This may not look as flashy, but it is stable, and it lets you judge depth and distance well enough to terrain-follow manually - if you are up to it.

More ⟵ DETAIL ⟶ Less
Textured Plain
Slower ⟵ SPEED ⟶ Faster

Horizon

This allows you to choose between a smoothly graduated horizon ('Faded') and a plain blue sky ('Plain'). Click on the option of your choice.

More ⟵ DETAIL ⟶ Less
Faded Plain
Slower ⟵ SPEED ⟶ Faster

Sky

This switch allows you to turn the thin layers of individual clouds on (textured) or off (Plain). The overcast effect (a thick solid cloud layer) will not be affected.

More ←	DETAIL	→ Less
Textured		Plain
Slower ←	SPEED	→ Faster

Ironwork

This peculiarly-named switch controls whether you will see the cockpit canopy framework and the brackets supporting the Head-up Display. Turning this switch off will speed up the frame rate considerably on slower computers.

More ←	DETAIL	→ Less
On		Off
Slower ←	SPEED	→ Faster

Control Device

This switch allows you to select which of a range of possible devices you will use to fly the aircraft. Click on the Cycle button repeatedly to see the range of options available, then leave the desired option showing. The options available will differ from one computer to another; those described here apply to the PC version, but users of ALL machines should check their Technical Supplement for changes:

Keyboard 1 Pitch and roll control by numeric keypad / cursor keys. Control input increases the longer you hold the key down, but returns to neutral when the key is released.
Keyboard 2 Pitch and roll control by numeric keypad/cursor keys. Control input increases the longer you hold the key down. When you release the key the control input stays at its last level - if you want to stop rolling or pitching you've got to make an opposite input, or hit the Autotrim key (5 - numeric pad).
Joystick 1 Pitch and roll control by single analogue joystick in game port 1.
Joystick 2 Pitch and roll control by analogue joystick in port 1, throttle and rudder control by second analogue joystick in port 2.

Recalibrate Joystick
This button is used to ensure that the computer recognises the centre position of your joystick(s). Let the joystick spring to its centre position and then click on this button. If you find that the aircraft is developing a persistent roll or a tendency to climb or dive, it is almost certainly because your joystick centre position is drifting over time. You can recalibrate in flight by centring the stick and hitting the Y key.

Sound and Music Preferences

Sound hardware varies a lot between computers - even between PCs. Check the Technical Supplement for your machine to sort out the specific details. There are two options which will always be present on this page, however:

Effects
There are three 'radio buttons' for this option. 'Off' switches off all sound effects; 'On-Eng' gives you all sound effects except the noise of your own engines, and 'On+Eng' gives you all sound effects including your own engine noise.

Music
This switches the front-end incidental music on or off.

Miscellaneous Preferences

This is a catch-all group with a lot of unrelated options in it.

Review Stills

The digitised pictures of aircraft and vehicles available in Review mode (see below) are high-quality images, but they do take up a lot of disc space. If you have installed a working copy of Tornado on a hard disc and you want to reclaim the disc-space used by these images you can click on the 'Delete' button here to remove them from the installed copy. When you have deleted these images, you can only get them back by re-installing the program.

Panel Lighting

This switch allows you to select red or green cockpit lighting for flying at night. Real Tornados may be fitted with either option, and we thought that both looked good. The brightness of the cockpit lighting is set according to how dark it is outside, and you can also adjust the HUD contrast to avoid dazzling yourself on a dark night (see the Cockpit Controls section on the Control Summary card). We recommend dimming the room lights when flying at night.

Curve Segments

On the Mission Planner map, curves are drawn in flightplans wherever you change course. When there are a lot of curves (and a lot of flightplans) to draw, producing smooth curves can take up a surprising amount of computer time - a smooth curve has to be drawn as a lot of short straight lines. The 'radio buttons' for this option allow you to choose how many lines will be drawn to represent a curve.

Smoother ←		CURVE		→ Coarser
32	16	8	4	2
Slower ←		SPEED		→ Faster

Contour Interval

Contours are shown on the Mission Planner map to give you an idea of the height and shape of hills. Like curve-drawing, this can consume a lot of processing power and slow your machine down noticeably. These 'radio buttons' let you select the interval between contours in feet. The lowest contour drawn is always the 250' line.

More ← CONTOURS → Fewer

250 500 1000

Slower ← SPEED → Faster

Windows

This option may not be available for all versions. When it is, you have a choice between see-through windows and solid ones. On the Mission Planner map, transparent windows let you see through the window to the map, but solid windows are drawn faster.

Transparent ← WINDOWS → Solid

Slower ← SPEED → Faster

EXPLORE

Explore Mode is a highly useful feature which is also good fun. When you select the Explore option the screen changes to show you a full-screen window onto a map of the current Flying Area. When in Simulator or Training modes, this will always be the Training Area, but when you select Combat, the Mission Selection Screen provides the facility to choose any one of three different War Zones. If you move the mouse pointer against any screen edge, the screen window will be dragged across the map in the corresponding direction. Click on the LEFT mouse button to zoom in, click RIGHT to zoom out. Note that when you do this the point under the mouse pointer will be moved to the centre of the screen.

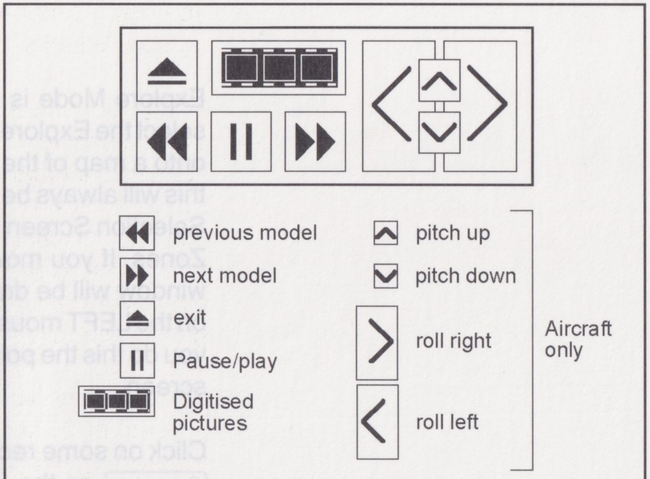
Click on some recognisable feature (a city or an airfield, say), and then hit the Spacebar or the Enter key. You will find that your view is now that of a disembodied eye floating sixteen feet above ground level at the spot you clicked upon. Using the keyboard, the mouse or joystick(s) you can now move at will in three dimensions at high speed, or hover on the spot. You can go almost anywhere and see anything except the positions of aircraft and vehicles.

At any time you can flip back to the map screen, click on another point as far away as you like, and then return to the three-dimensional world at that spot. You can use this system for entertainment, for familiarising yourself with the landmarks, or within the Mission Planner to find out how your target will appear as you approach it. The military term generally used for this is Mission Rehearsal, and armed forces everywhere are trying to acquire this sort of facility, for obvious reasons.

You will find a complete list of the Explore Mode controls in the separate Control Summary. To leave Explore mode, hold down the Ctrl key and hit Q.

REVIEW

The Review feature allows you to see digitised photographs of the aircraft and military vehicles you will encounter, and compare them with the 3D models representing them in Tornado. There are two main purposes for this: on the one hand it helps you develop the ability to recognise friendly and enemy hardware. On the other, it shows off the models, of which we are very proud. The guiding principle in constructing these models has been that if you can recognise the real thing you should be able to recognise the model, and vice versa.



Review Mode Schematic

diagram 2.2

When you enter Review mode, you will see the screen split between an upper display area where the models are shown and a lower area showing the aircraft or vehicle name with a control panel. The icons on the panel are explained in *diagram 2.2*. Clicking on the film-strip icon displays a full-screen digitised picture. To return to the model display just click on either of the mouse buttons. Keystrokes can be substituted for some of the mouse commands (see the Control Summary). If you want more detailed information on a particular aircraft or vehicle, look it up in the Reference section of this manual. To leave Review mode hold down the Ctrl key and hit Q, or click on the Eject button.

LOGS

The Pilot Log system is a schizophrenic's paradise; it allows you to be up to 20 different people. Any time you're flying a Tornado, you are doing so under one of these 20 possible identities, with a name, a nominal RAF rank and a record of flying hours and experience. Most of these identities you create for yourself by choosing a name and typing it in, but one is special - the default log. This log is supplied with the software, and is automatically selected every time

you start Tornado. The log is in the name of Group Captain deFault and you can use it just like any other log, but it has several interesting features.

One of Group Captain deFault's good points is his rank - equal to the highest available in Tornado. Using this log identity you are automatically qualified to play the Command wargame, which is only open to pilots who have earned the notional rank of Wing Commander or above (see the table of RAF ranks below). You can earn promotion for a pilot whose log you created yourself, but this sort of rank is not awarded lightly. See the Flight Options chapter to find out how to win promotion - we have made it possible to skip ranks if you are good enough.

The other good thing about Group Captain deFault is that he is indestructible. You are not - do not attempt to emulate him. Actually, that is not quite true - it depends on your attitude to cheating. See the section below headed 'Cheating'.

Whenever you play a Quickstart game, the deFault log will always be used, regardless of which log is selected.

Using the Log Screen

The Log Screen looks rather like the Mission Selection Screen, which you will come across elsewhere. The left-hand half of the screen is dedicated to displaying the Roster, a list of all existing pilots, by rank, name and status. A pilot's status may be Active, Missing, POW (Prisoner of War), KIT (Killed in Training), KIA (Killed in Action) or Dismissed. Only pilots with Active status can fly. Initially there is only Group Captain deFault's name on the list. As you create identities for yourself, the list will expand downwards to its maximum of 20 names, in descending order of rank and experience. For reference, here are the RAF ranks we have unilaterally borrowed to indicate levels of experience and achievement, together with their USAF equivalents:

RAF	USAF
Group Captain	Colonel
Wing Commander	Lieutenant-Colonel
Squadron Leader	Major
Flight Lieutenant	Captain
Flying Officer	Lieutenant

In real life, the relationship between RAF ranks and the size of the units led has changed since the ranks were named not long after the First World War. In general, a Wing Commander now commands a Squadron, and a Squadron Leader leads a Flight. The majority of operational aircrew hold the rank of Flight Lieutenant.

One of the names on the list will always be selected and highlighted. A smaller window on the right-hand side of the screen (the Record window) shows details of the selected pilot's record. When more than one name appears on the Roster, you can select which log to display by clicking on the name you want.

If you call up the Log Screen after selecting the 'Command' wargame option, only the logs of qualified pilots will be shown on the Roster.

Creating, Deleting and Renaming Logs

Buttons labelled 'Create Log', 'Rename' and 'Delete Log' appear on the right-hand side of the screen. These buttons will automatically be enabled and disabled depending on the situation. The 'Create Log' button will only be available if there are less than 20 names on the Roster. If the Roster is full and you want to create a new identity, you must first delete an existing log. This is done by clicking on a disposable log to select it, then clicking on the 'Delete Log' button. You will then be asked to click again to confirm that you really do want to lose this log. 'Delete Log' will not be available if the currently selected log is that of Group Captain deFault.

Clicking on the Create button brings up the Record window with a blank name and record. You can now type in the name you want, using Backspace to correct mistakes. When you are finished, click on the 'OK' button at the bottom of the Record window, and your new pilot will be added to the roster. All new logs are created with the rank of Flying Officer.

If you want to rename an existing pilot, select that log by clicking on the Roster and then click on the Rename button. This will activate the text cursor on the name line in the Record window, and you can use Backspace and type in the normal way. Click on OK when you are finished.

Leaving the Log Screen

When you have selected the Log you want to use, click on the Exit button in the lower right corner to leave this Screen. If the Log you have selected is not that of an Active pilot, a small window will appear to remind you that you cannot leave this screen until you have selected an Active log to use. The warning window will not disappear until you have done this, but it can be dragged out of the way.

Cheating

Everyone's luck must run out sometime, especially if you make a habit of relying on it. In our last major simulator, 'F-16 Combat Pilot', pilots who were killed or captured had their logs deleted, period. There were ways to get around this (like backing up your log files), but we received a lot of anguished 'phone calls from people who could not bear to lose their hard-earned records and privileges. This time around we have left it up to you to decide whether or not to accept the fortunes of war.

At the end of every flight you will get a Debrief, and unless you are using the deFault log you will be offered a choice between logging the mission or wiping it off the record. IF you choose to log it, the hours flown and any other

achievements will be added to your record - and if you did not make it, the status of the log will change to 'Missing', 'POW', 'KIT', 'KIA' or 'Dismissed'. There is no way back once the mission result is logged, so do not do this unless you are prepared to suffer the consequences. You cannot get killed or captured in the Simulator, or in a Two-Player engagement. When you choose to log the result, you will be returned to the Mission Selection Screen, the Mission Planner, or the Flight Options screen, depending on the type of mission you were flying and its outcome.

If you choose NOT to log the mission, however, absolutely no changes will be made to your log - it will be as if the mission never happened. If you came through the Mission Planner, you will return to it with your last flightplan still intact (the clock will be set back if it is a Campaign or Command mission), so you can either try it again or exit from the Mission Planner in the normal way.

THE QUICKSTART USER'S GUIDE

or

(The Tornado manual for the terminally impatient.)

This brief section tries to give you the bare minimum information to try out the Easy Quickstart options without running into instant frustration. We cannot hope to accomplish more than that in a few paragraphs. Once you have had a quick blast, go back to the first chapter (Finding Your Way Around), and use it to figure out what you really need to read. All key references below correspond to the PC version. Check your Control Summary for correct control keys if you are not using a PC.

Unlike many other simulators, Tornado does not provide an 'arcade spaceship' flight model with unlimited engine power and instant acceleration or braking - you will have to learn to live with the limitations of a realistic aircraft. For the Quickstart options, we have made things much easier by giving you an aircraft that ignores the weight of fuel, bombs and missiles and behaves as if it were

carrying nothing but its own empty weight, though your fuel gauge will show full and your weapons will be replaced the moment you use them. You will also start off with the Autothrottle engaged, so the engines will throttle automatically to keep you at a set speed, which you can change up and down by using the throttle control device (+ and - keys or a second joystick).

The most important difference between a Tornado and most other aircraft is that the Tornado has variable-sweep wings. You sweep these forward to manoeuvre better at low speeds, and back to accelerate to high speeds. If you try to go too fast for your wingsweep setting, the aircraft will start to shake and rumble, if you persist a warning will sound - go on too long and the aircraft will shake itself to pieces.

You can prevent this by sweeping the wings back at the first sign of trouble. There are three stages of wingsweep, and each time you hit the S key, the wings will sweep back one stage. To turn off the warning if it sounds, hit the Master Warning Reset key (* or ' key). This will turn off the flashing lights provided that you have fixed the problem, though the wing sweep system will jam in one position if you neglect the buffeting for too long. If you are flying slowly, and the aircraft will not turn fast enough - or stops flying and drops its nose, sweep the wings forward by hitting the W key - once for each stage.

If you are on an air-to-ground mission, just hit the Arm air-to-ground key (Enter key). This will arm your bombs and give you a bombsight on the Head-Up Display (HUD). Your bombload is set to drop in Manual mode, which means that when you hit the Commit key (Spacebar or joystick button), the bombs will be released immediately, and they should fall where the short horizontal line (the CCIP) crosses the longer vertical one with a gap near the top (the Bomb Fall Line). If the top of the Bomb Fall Line is below the CCIP, it means that you're too low - the aircraft will probably be damaged or destroyed when the bombs go off. In Quickstart mode you can attack anything you like.

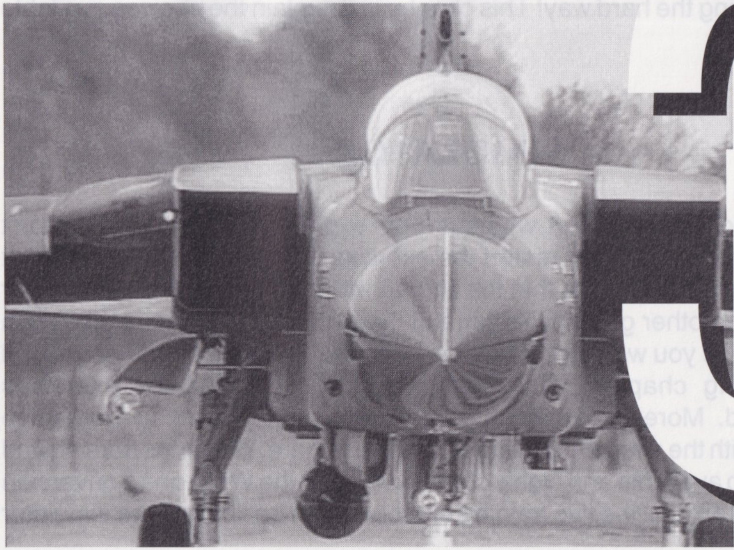
When you use the Air-to-air option, the first thing you must do is turn on the radar in Air mode (Alt + R), which will bring up a plan display of the radar image on the central Multi-Function Display (MFD). Enemy aircraft in front of you will

be shown as small square symbols. You must also hit Arm air-to-air (Alt + Enter). Now you can select which air-to-air weapon you want (; key). In the Tornado ADV you have three air-to-air weapons to choose from; cannon for close range (GUNS), heat-seeking short-range Sidewinder missiles (AIM9), and medium-range (up to 20 miles) radar-guided Active Sky Flash missiles (SKYF). The final thing you have to do is lock on to your target. There is a Designate key (Caps Lock), which will select the target closest to dead-ahead. The symbol on the radar will now flash, and a target designator and other sighting symbols will be shown on the HUD. Be aware that the radar can see further than the seeker head on the Sidewinder missiles - you will not be allowed to fire until the missile can see the target and you can hear the lock-on tone.

Refer to the Aircrew Notes , Chapter 11, to find out what the HUD symbols mean.

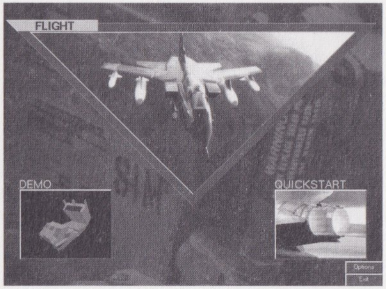
FLIGHT OPTIONS

CHAPTER 3



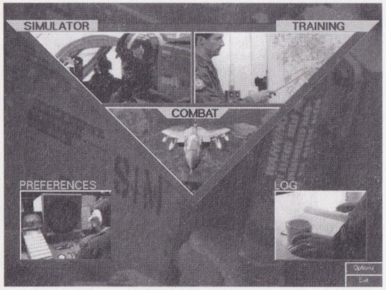
FLIGHT OPTIONS

In the centre of the Main Screen is the large triangular 'Flight' icon. Click on this with the mouse pointer, and it divides to offer three choices: Simulator, Training, and Combat. At the same time the Demo and Quickstart icons will be replaced by icons for the Log and Preferences facilities. Clicking on these icons produces exactly the same result as selecting the corresponding items in the 'Options...' menu, which is still available on this screen. If you want to go back in order to select Demo or Quickstart, click on the 'Exit' button in the bottom right-hand corner.



Main Screen

TORNADO caters for a very wide range of skill and knowledge. In the simulator or in live training a novice can learn how to fly, or an experienced pilot can become familiar with the aircraft and its systems and perform practice attacks with every available weapon. When you're ready, and not before, click on the 'Combat' icon to go to war - but don't start with the Combat option unless you insist on learning the hard way! This chapter will explain the choices available to you.



Simulator, Training or Combat

SIMULATOR

This is the logical place to start, whatever your experience level. Crashes don't matter in the simulator - just restart the exercise and repeat it until you don't crash. You can even arrange that the aircraft will bounce off the ground rather than crash! The other great advantage of the simulator is that exercises can start in mid-air. If you want flying training, read the Elementary and Advanced Flying Training chapters, and work through the simulator exercises recommended. More experienced pilots will probably want to familiarise themselves with the aircraft handling and systems here. Weapons training and practice is also available and highly convenient - see the Weapons Conversion chapter for details. All the live training exercises can be flown in the simulator

with optional simulated enemy activity. There are also a number of exercises unique to the simulator, allowing you to practise emergency procedures like spin recovery, engine-out handling and landing, and landing with your wings stuck at maximum sweep. The simulator also provides a good range of 'cheat modes'.

If you are using a log you have created yourself, flight time in the simulator will be recorded, though it will be logged as 'Simulator Hours' rather than 'Flying Hours'. It still counts as experience. Simulator exercises always take place over the Training Area.

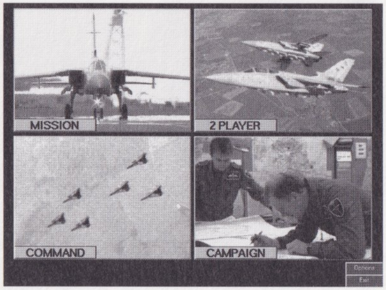
TRAINING

This offers live flight training. No-one will be shooting at you, but you can still kill yourself. You can avoid the consequences of your errors altogether if you wish - see the Pilot Log section under 'Options' (and look for the heading 'Cheating'). Live flight exercises must obviously start and finish on the ground - preferably on the runway. This facility mainly serves as a confidence-builder once you have developed your skills in simulator exercises. Live training always takes place on the Training area map.

COMBAT

If you select 'Combat' then you're going to war. Don't select this option until you're ready for it. There are four different sub-options available, each of which is described below. If you are new to this sort of warfare, start working through the 'Mission' list. If not, fly a 'Mission' or two for practice and then go straight to the 'Campaign' options. A successful Level 2 Campaign is the only way to qualify for 'Command' in your own right, though any pilot may try out 'Command' using the log identity of Group Captain deFault. Combat allows you to select and fight in any Flying Area except the Training Area.

After clicking on the 'Combat' icon, you are presented with a new screen showing four icons giving you a choice of four different types of play:



Combat Selection Screen

Two-Player lets you connect your computer to a friend's and fight a human opponent one-to-one. The connection may be made directly or by modem. Any rank of pilot may use this facility. See the Technical Supplement for further details.

Mission lets you choose from a selection of completely pre-planned missions. Each mission is a complete game in itself, and the outcome of any one mission has no effect on any other. This option is available to any rank. If any pilot successfully completes all the missions, (s)he will be promoted to Flight Lieutenant, unless the current rank is already greater. Two Missions are different from all the others in that they are not pre-planned. These are the missions titled 'Free Fire (IDS)', and 'Free Fire (ADV)' where no targets are assigned and you are free to attack whatever you like. These missions are intended to serve as an introduction to the job of planning missions for yourself.

Campaign lets you choose from a selection of scenarios. Each one requires you to fly a sequence of missions to achieve a final objective. The individual missions are not pre-planned in detail for you, but the objective for each is specified. The situation at the start of each mission reflects the success (or otherwise) of the previous one. The Campaign state may be saved at the end of each mission, to be continued later. This option is available to any rank. Campaigns are graded into two levels. In a Level One Campaign, you will be responsible for creating flightplans for just one aircraft - your own. In a Level Two Campaign, however, you must plan missions for a whole formation. Successful completion of a Level One Campaign will earn the pilot a promotion to Squadron Leader, whatever the current rank, but successful completion of a Level Two Campaign yields a promotion to Wing Commander.

Command gives you total command authority to conduct your own air war. You must decide your own objectives as well as plan the missions and fly a proportion of them. The war continues until you win, lose or reach a stalemate,

but the status can be saved and reloaded so you don't have to fight your war in one continuous session.

n.b. Only qualified pilots (with the rank of Wing Commander or above) can assume Command. Group Captain deFault is already qualified, but any new pilot only qualifies when (s)he logs at least one successful Level Two Campaign. A successful Command earns a promotion to Group Captain.

WHAT HAPPENS NOW?

Whether you select Simulator, Training or one of the Combat options, you will always find yourself on the Mission Selection Screen, which allows you to choose exactly what you will be doing, a specific Simulator or Training exercise, or a specific Combat situation. The Mission Selection Screen is described in detail in the next chapter.

If you have selected Simulator, you may progress from selecting a given exercise straight to the cockpit. In all Training and Combat situations, and some Simulator exercises, however, you will move from the Mission Selector on to the Mission Planner, to review or create your flightplan or take command of your war. The Mission Planner is described in detail in a chapter of its own.

Once you have reviewed all the relevant data - at a minimum this will be your own flightplan - and familiarised yourself with the target(s), the method of attack, and the threats from SAMs, AAA and fighters on or near the route, you will be able to check your aircraft's fuel and weapon load, and add defensive weapons - weight permitting.

When this is done, the mission flightplan is loaded into your aircraft's navigation systems, and it's time to take off. When the mission ends - one way or another - you'll receive a debrief assessing your performance. At this point you will have the choice of whether to log the mission or not. If you've died or gone missing, but think this was unfair, DON'T LOG THE MISSION or else your log

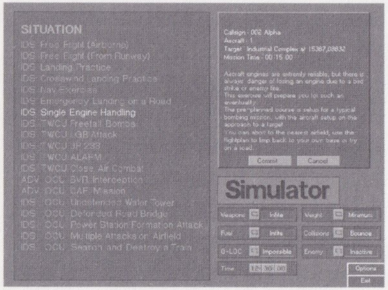
will be closed (this doesn't apply to Group Captain deFault, who is indestructible). If the mission was unsuccessful, or if you just want to do it again for practice, you can return to the Mission Planner, review or adjust the flightplan and then select 'Take-off' to go straight back to the cockpit.

THE MISSION SELECTION SCREEN

CHAPTER 4

THE MISSION SELECTION SCREEN

There are two main sections on this screen. The large area on the left is the Situation Menu - a list of all the situation options which apply to the Flight mode you've selected:- simulator or training exercises, single missions, Campaign Scenarios and saved games, or Command Scenarios and saved games.



Mission Selection Screen

What you see on the right-hand side of this screen depends entirely upon the Flight Mode. This area is used to offer choices specific to each mode. See the separate sections below for details.

THE SITUATION MENU

Whichever Flight Option - Simulator, Training or Combat - brought you to this screen, this part of the Mission Selection screen will always look much the same, and work in much the same way - very much like the Pilot Log system. It offers you a list of situations or scenarios, from which you must select one. The range of situations offered will automatically be limited to those appropriate for the Simulator, Training, or whichever Combat option you have chosen.

Each item on the list is a one-line description or title. To take a closer look at a possible choice, click on the line you're interested in. A new window - the Briefing window - will appear on the screen giving a fuller description, which may (depending on the situation) include such things as the Tasking Order specifying the target(s), times and the number of aircraft, a summary of a complete Flightplan, the description of the military situation at the start of a Campaign or Command game, or a situation summary for a saved game.

Two buttons will always appear at the bottom of this window; one marked 'Commit' and the other marked 'Cancel'. If this situation or mission appeals to you, and you want to do it, click on 'Commit' to advance to the Mission Planner, or straight into the cockpit in the case of some Simulator exercises. You can still reverse your choice if necessary, by using the the 'Options../Exit' device in the Mission Planner, or Ctrl Q in the cockpit. If you want to go back to the list and look at other possibilities, click on 'Cancel', and the Briefing window will close, returning you to the Mission Selection list. There is no penalty for browsing.

Situation Menu for Simulator

A wide variety of training exercises are available here, some of which will pass you on to the Mission Planner, and some of which will put you straight into the cockpit in flight.

Situation Menu for Training

These are a selection of training exercises to be flown live. Because these are 'real-world' exercises none of them permit you to start in mid-air. Crashes can and usually will be fatal, striking unplanned targets will normally be cause for court-martial.

Situation Menu for Missions

Every mission here is pre-planned for you - except the missions titled 'Free Fire'. The range covers almost everything you can do with IDS and ADV Tornados. A range of missions exists for each of the three different War Zones, so there's a good deal of choice. The relative difficulty level is indicated in the Briefing Window for each mission.

Situation Menu for Campaigns

The selection list for Campaigns is divided into sections. The upper of these sections is a list of scenarios, alternative starting situations for a Campaign mission sequence. Each scenario is tagged as Level 1 or Level 2, according to whether you will be expected to plan missions for 1) just your own aircraft, or 2) your whole flight. Level 2 requires more experience than Level 1, and obviously involves more work. There is an equivalent list of Campaign scenarios for each of the three War Zones.

The lower section of the list is available for saving and loading uncompleted Campaigns. If you exit from the Mission Planner in the middle of a Campaign, you will be asked whether or not you wish to save the game in order to return to it later. Saved games in the list are identified by scenario, Pilot Log name, and elapsed time within the campaign. You can save one Level 1 and one Level 2 Campaign per War Zone at any one time, a total of six. To reload a saved Campaign, just click on the appropriate slot in the list. The Briefing Window will provide a situation summary with the usual Commit and Cancel buttons.

Situation Menu for Command

This works very much like the Campaign menu described above, providing a list of alternative starting scenarios and one saved game slot per War Zone.

Situation Menu for Two-Player Mode

For details of how the two-player option works on your computer, consult the Technical Supplement.

OTHER OPTIONS AVAILABLE

Choice of War Zone (Combat Modes)

This applies only to Combat Flight Modes; Simulator and Training exercises always use the Training Area. In all Combat modes except Two-player you have the choice of three War Zones, each with different topography presenting a variety of strategic and tactical challenges and opportunities.

When you enter the Mission Selection Screen in Combat modes, a map image of the currently selected War Zone is shown on the right-hand side of the screen. To the left of the title showing "War Zone 1" (or 2 or 3), is a small button showing a circle / arrow symbol. This is a Cycle button, and clicking on it will select each War Zone in turn. You will see many other Cycle buttons in the Mission Planner and elsewhere in Tornado, but they all work in the same way; clicking repeatedly on the button selects each option in turn from a range of two or more choices.

Simulator Options

This bank of switches controls features which can be provided in the simulator but are impossible in the real world. For every feature except Time there is a just one control; a Cycle button. Click on the Cycle buttons to set up the options you want. The list incudes:

Feature	***Options***
Weapons	Limited / Infinite
Fuel	Limited / Infinite
G-LOC	Possible / Impossible
Aircraft Weight	Actual / Minimum
Aircraft Collisions	Crash / Bounce
Enemy	Active / Inactive
Time	Set any start time on 24-Hour clock

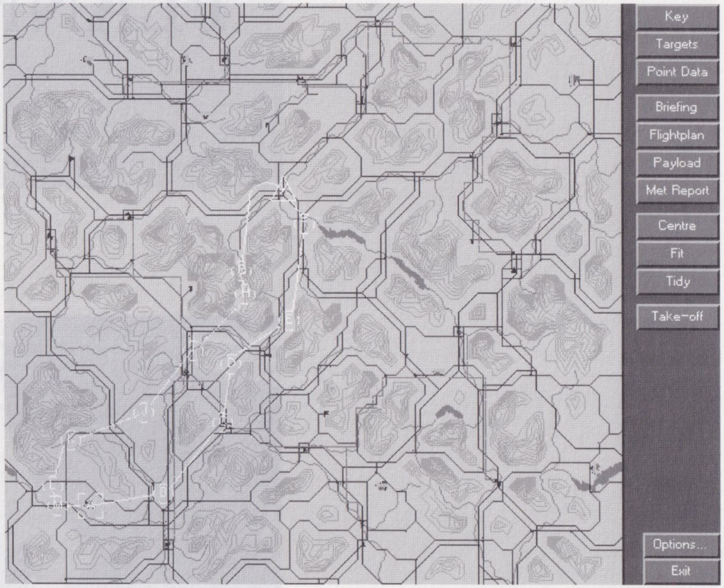
The Time option can be used to specify whether you fly in daylight, dawn/dusk, or varying degrees of darkness. Hours, Minutes and Seconds each appear on a separate button. Click on the button for Hours, for example, and two separate buttons marked with arrows will appear above and below the Hours figure. Clicking on these will set the time forward or back. A single click will change the time by one hour; click and hold down the button for fast forward and fast reverse effects. Clicking again on the figure itself or on another column (e.g. minutes or seconds) will dismiss the arrow buttons. When the Simulator mission takes you to the Mission Planner rather than straight into the cockpit you can override the time selection again from there, if you wish.

THE MISSION PLANNER

CHAPTER 5

THE MISSION PLANNER

INTRODUCTION



Mission Planning

This is the most important and the most powerful screen of all. Using it you can review or plan a single mission or a squadron's flightplans for a whole air-war down to the smallest detail. A vast amount of information is available, but you have absolute control over what is and is not displayed.

Before you try to study this chapter in depth, we strongly suggest that you learn how to fly the aircraft and use the weapons. Mission planning doesn't really make much sense till you're ready to fly missions.

How this chapter is organised

Because the Mission Planner is so powerful and so rich in features, there is a lot of ground to cover in this chapter. Rather than force you to read it all from start to finish, we have broken the explanation down into three sections of which the beginner need only read the first.

The first section covers the basic features of the Mission Planner, showing you how to move around the map, how to zoom in and out and how to use the Key to control how much data is displayed on the map. This section teaches you

SINGLE MISSIONS		—	Missions planned for you, (except free fire)
or			
CAMPAIGN	level 1 (single aircraft)		Tasks defined, you plan the mission
	level 2 (multi-aircraft)		
or			
COMMAND		—	You select targets and plan mission

Mission/Campaign/Command

diagram 5.1

how to review a preset Flightplan, and covers all you need to fly single Missions.

The second section is intended for pilots aiming to plan their own missions, whether for a 'Free Fire' Mission or to fly at Campaign level. It assumes that you have read and understood the first section, and explains how to create a Flightplan first for a single aircraft (Free Fire or Level One Campaign), and then for a whole flight of aircraft (Level Two Campaign).

The third section covers the features you need at Command level. It assumes that you are familiar with the material in the first two sections.

SECTION 1 - USING THE MISSION PLANNER - BASICS

Select and Commit on any one of the Simulator or Training Missions with the prefix 'IDS - OCU' so that you can reach this screen (you won't have to fly the mission if you don't want to). You'll see a map in front of you, and a number of buttons down the right-hand side. We will refer to these in future as 'Map Screen Buttons'.

Many of these buttons call up sub-windows on the screen, and several of these may be present at the same time. Every sub-window has a Title bar with a Close Box allowing the window to be dismissed or dragged. Windows may overlap one another, but right-clicking on any visible portion of a window will put it 'in front' of any overlapping windows. You can close them all at once with the 'Tidy' button.

Map Screen Buttons

In order from top to bottom, the buttons read:

Key
Calls up the map Key, see below.

Targets
Used at Campaign level and above. Works in conjunction with the Category Flag to highlight all potential targets of a given kind. See Campaign section.

Point Data
Clicking on this button will bring up the Point Data Window. This gives details about the point on the map under the mouse pointer, including the grid coordinates, the ground height above sea level, the nearest structure (if any), the estimated 'floor' of radar coverage at that point and the current ownership (Allied or Enemy). The information in this window is only updated when the mouse is stationary.

Briefing
For Simulator Missions, or single Combat Missions, the button reads 'Briefing', and calls up a window with an outline description of the mission, identical to the description you were offered when selecting the mission. At Campaign level it will read 'Task', and at Command level it will read 'Command', and will function differently. See the appropriate sections for details.

Flightplan
This button is used to bring up the Flightplan Window, which allows you to review, modify, or create flightplans for your own (and potentially other) aircraft. See below.

Payload
This button calls up the Payload Window, which is used to verify fuel and weapons load, and to load weapons for self-defence or attacks on targets-of-opportunity. See below.

Met. Report

This button calls up a weather (Met. for Meteorological) report giving wind direction and strength plus visibility and cloud heights. In the Simulator, some of these factors can be changed. See below.

Centre

This button zooms the map right out and centres it on the screen, so that you can instantly call up the big picture from wherever you are.

Fit

Clicking on this button will automatically set the zoom level and scroll the map so that the whole of the 'current' flightplan is visible on the screen at once.

Tidy

If you feel that the map is in danger of disappearing behind a solid sheet of overlapping windows, clicking on the 'Tidy' button will close all open sub-windows at once, except the Problems Window, which can only be dismissed by fixing the problems it's bringing to your attention. See the second section for details of the Problems Window.

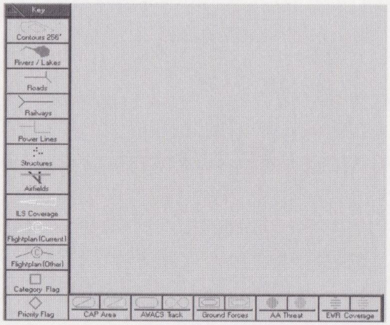
Take-off

When you've studied the briefing, the flightplan, the payload and the Met. report, click on this button. Provided that there are no major flaws in the flightplan, you will find yourself in the cockpit on the runway, after a pause to download the flightplan to your aircraft's navigation systems.
If the Problems Window (explained later) is active and showing an 'ERROR' message, there's something drastically wrong with your flightplan, and you won't be allowed to take off until it's fixed. This should never happen if you are simply flying preset single missions. The fun starts when you begin planning your own.

The Key Button

Click on this button and a 'frame' of panels/buttons will appear down the left side and across the bottom of the screen showing the map symbols and their meaning. Like any other sub-window on this screen, it can be turned off by clicking on the Close button in the top left corner.

The Key display is not just a passive display to help you identify map symbols. Each of its panels showing a symbol and its identification is also a button which controls whether or not that symbol will be drawn on the map. Using this feature, you can avoid cluttering the display with symbols you don't need or want to see. To turn any symbol on or off, just click on the appropriate panel of the Key window. This can also be used to speed up the redrawing of the screen if your machine is running more slowly than you like - just turn off everything you think you can do without.



Key Buttons

When you first enter this screen the Key will be set to display just Physical data (contours, rivers and lakes), and Cultural data (roads, railways, power lines, structures, etc.), plus the Mission Flightplan or Task outline. Some of the symbol options relate to more advanced features which we will deal with later.

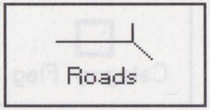
In order from top to bottom down the left side:

Contours

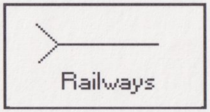
Contour lines are shown for hills at variable intervals above (flat) ground level. Because drawing contours is a demanding task which can reduce a slow computer to a crawl, the vertical distance between contour lines can be set from the Preferences screen (available through Options...). The lowest contour is the 250-feet line, and this is always drawn, whatever the interval setting.

Rivers and Lakes

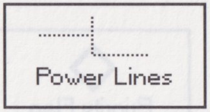
Self-explanatory.



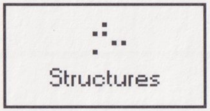
Roads
Self-explanatory.



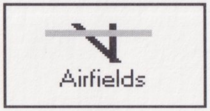
Railways
Self-explanatory.



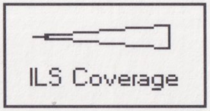
Power Lines
Self-explanatory.



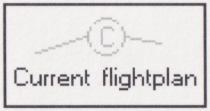
Structures
Symbol for buildings, bridges or embankments.



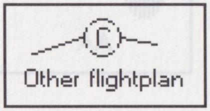
Airfields
The runway layouts of the airfields themselves are always shown on the map, with the active runways distinguished by colour. This button acts only to turn the airfield name label on or off.



ILS Coverage
If your aircraft is within the ILS symbol and pointing in the general direction of the runway, your ILS (Instrument Landing System) will be active, and you may use it either to make an automatic approach or to guide a manual approach.

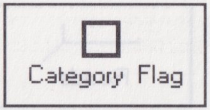


Flightplan (Current)
When a preset mission is loaded, your flightplan will be shown. At Campaign level and higher, this indicates the flightplan (among several) which you are currently reviewing or altering. Where the flightplan shows a change of course as you leave one waypoint and turn toward the next, a curve will be drawn. How smooth a curve you see is selectable from the Preferences Screen (accessible through 'Options'), because drawing a large number of smooth curves can be a heavy burden on slower computers.



Flightplan (Other)
When more than one flightplan is shown on the map, the ones which you are not currently reviewing or editing will be shown in a different colour.

Category Flag



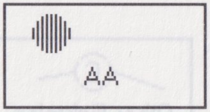
This symbol is used by the Target Finder facility to highlight all potential targets in a particular category, for example road bridges, control towers, stores dumps etc. This feature is useful for the 'Free Fire' Mission and at Campaign or Command Level. If you use the 'Targets' button to call up the Target Finder this feature will be turned on automatically, and when you close it again this switch will return to its previous state, whether on or off. If the Category Flag is enabled in the key, the category symbols will still be shown even if the Target Finder is dismissed.

Priority Flag

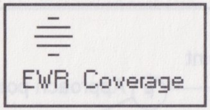
This symbol is used by the Command Target Priority facility to highlight positions which are important targets for one reason or another. This feature is only used at Command level. Like the Category Flag, this feature will be turned on automatically when the Target Priority system is in use, and restored to its previous state afterwards.

The other buttons along the bottom edge of the strip, are 'split' buttons. Each is divided into three areas. These comprise the allied and enemy versions of the same symbol and the area below containing the legend text. Enemy symbols will normally appear in orange and allied in blue (check with the Technical Supplement for your machine if they don't). Clicking on the symbol areas has just the effect you would expect - display of the allied or enemy symbols is turned on or off individually. Clicking below in the text area, however, INVERTS the selection state of both allied and enemy symbols at once - it gives you the exact opposite of what you have at the moment. In other words, if both allied and enemy symbols are off, clicking below will turn both on, clicking again will turn both off, but if, say, allied are on and enemy are off, clicking below will turn allied off and enemy on. From left to right the buttons are:

AA Threat

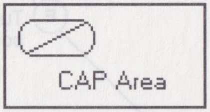


Areas known to be covered by AAA or SAMs are shown like this. The area shown illustrates the maximum effective range of the system deployed, and does not take account of terrain masking or range variation with altitude. Positions are not guaranteed to be precisely accurate.



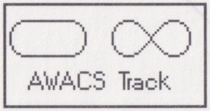
EWR Coverage

Shows areas within theoretical range of Early Warning Radar stations. Does not take account of terrain masking - but you can get this information from the Flightplan Profile Window (see below), or from the Point Data Window.



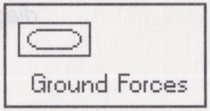
CAP Area

Indicates a fighter CAP (Combat Air Patrol) area. Enemy positions are estimated, allied positions should be exact. This should give you some idea of where you might expect to find help or opposition.



AWACS Track

Shows the exact (allied) or estimated (enemy) 'racetrack' which an AWACS aircraft flies when on station. Note that the enemy AWACS flies a figure-of-eight rather than a plain oval. AWACS is not always available to either side, but when it is, interceptors will function more efficiently to defend the side(s) possessing it. The AWACS aircraft itself is a very high-value target.



Ground Forces

Standard military symbology for an armoured unit, this is placed at known locations of major ground force formations on the battlefield, in close reserve, or en route to the battle area. Unless you actually plan to attack them, stay away from these forces - they're usually heavily defended.

Moving and Zooming the Map

Zoom Control

Moving around the map and zooming in or out are done with the mouse, using the RIGHT button. To move a point on the map to the centre of the screen, just point and click (right) on it. The map will be redrawn with the selected point in the centre of the screen. To zoom in or out, click (right) and hold down. A small strip of boxes corresponding to the zoom-levels available will appear under the mouse-pointer, with the pointer on the current zoom level. This works very much like the Options... button. Keep holding the mouse button down! You may go straight to any other zoom level you like by simply moving the mouse pointer over the appropriate box in the strip and releasing the (right) mouse button.

All about Waypoints

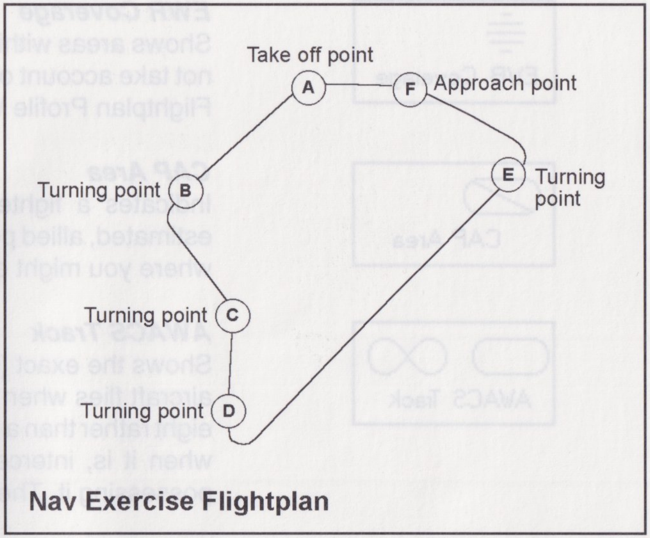


diagram 5.2

The flightplan for the mission you loaded has already been created for you, and should be visible on the map when zoomed out. If it isn't, you must have turned it off from the Key window - so turn it back on (using the panel marked 'Current Flightplan'). If you've worked through the Advanced Flying Training chapter then you've seen something like this on the navigator's PLN display. It's a series of lines connecting labelled symbols in the shape of boxes, circles and triangles, and will usually loop back to a place near its starting point.

A flightplan is composed of Waypoints and Legs. Waypoints are fixed points, represented by the symbols between the line sections, and a Leg is simply the path between one Waypoint and the next. Legs usually start with a curve and terminate at the next Waypoint as straight lines. Waypoints come in several flavours:

Take-off Point

The Take-off Point, which is always Waypoint A, is obviously at the airfield from which you take off.

Turning Points

Turning Points are simply places where you change course - these are by far the most common type. They are labelled with capital letters following on from A, and the planned flight passes through them in alphabetical order.

Initial Points

Initial Points are the Turning Points from which you start the attack run on a ground target. They are labelled in the same sequence as other Turning Points.

Targets
Targets are labelled with the letters X, Y and theoretically Z, for the first, second and (most unlikely) third planned targets of a mission.

CAP Start
This is used to set up a Combat Air Patrol station for ADV missions. The relative positions of this point and the next waypoint (the CAP End point) define an oval 'racetrack' for your aircraft to patrol while waiting to intercept incoming enemy aircraft.

CAP End
See CAP Start, above. ADV flightplans only.

Approach Point
The Approach Point should be placed at the end of one ILS beam of the airfield at which you intend to land - you can make the ILS beam coverage visible on the map using the Key. It is labelled in the same sequence as the Turning Points.

A Waypoint must obviously have a position on the map, and be one of the types listed above. But it will also have a lot of other data (call them attributes) associated with it. Here is a list of all the possible attributes:

Label
All waypoints have labels. This will be a single letter of the alphabet starting with A (for the Take-off Point) and continuing in order through the alphabet, except for Target waypoints, which will be labelled X, Y and Z in sequence.

Type
This will show one of:

Take-off		
Turning Point		
Initial Point for	(Target Label)	(IDS flightplans only)
Target		(IDS flightplans only)
CAP Start		(ADV flightplans only)
CAP End		(ADV flightplans only)
Approach Point for (Airfield Name)		

Position
Coordinates are displayed in the title bar of a waypoint window.

Head/Tail Wind
Only Take-off and Approach Points have this attribute. It gives the strength in knots of the component of the wind which is blowing from ahead (Head-wind) or from behind (Tail-wind) as you take off or land; if you've got a Tail-wind component you're taking off or landing in the wrong direction. This should not happen with preset missions unless you insist on editing the flightplan. If you want to do this - read section 2 of this chapter.

Cross-wind
Only for Take-off and Approach Points. This is the strength in knots of the component of the wind which is blowing across the runway as you take off or land. A strong crosswind can make an approach and landing quite difficult.

Time
All waypoints show a Time and Time Status. For a Take-off point, this is the take-off time. For all other waypoints it is the time at which you expect, or plan, to pass or attack this point. The Status will show 'Free', 'Fixed' or 'Bound'.

Refer to the second section of this chapter for the meaning of these terms, how to set the Time value, and a stern lecture on the knots you can tie yourself into by using this feature without understanding it.

Altitude
Every Waypoint type except Take-off Points will also have an altitude/ride height, and an AFDS Altitude Authority attribute. If the Altitude Authority is set at 'Altitude Hold', the AFDS system will fly the leg to this waypoint at the given BAROMETRIC altitude, i.e. height above sea level. If the Altitude Authority setting is 'Ride Height', the AFDS system will fly the leg Terrain Following at the Ride Height given, i.e. clearance above the ground beneath the aircraft. Refer to the second section of this chapter for the method of setting heights.

Speed
All waypoint types except Take-off show a Speed and Speed Status. This is the average speed at which it is necessary to fly the leg approaching this waypoint in order to arrive at the Time shown. You may choose to have this speed displayed as IAS (Indicated Air Speed), or Mach Number. The Speed at a Waypoint will also determine the radius of the turn at the start of the Leg to the next Waypoint. The Speed Status may be 'Free', 'Fixed' or 'Bound'. Refer to the second section of this chapter for the meaning of these terms and the method of setting speed. Like Time setting, this is a feature which must be used carefully.

Target
Target waypoints only. Shown on the waypoint window Title bar next to the map coordinates. Describes the target, e.g. road bridge, HAS, runway etc.

Package data: Weapon
Delivery
Salvo
Minimum recommended delivery height.

Target waypoints only. These parameters specify the Package of weapons to be used in attacking this target, and how the Package is to be delivered. Your aircraft's load of ground attack weapons is divided into groups called Packages intended for particular targets. Weapon Packages and weapons in general are covered in detail in the Weapons Conversion chapter. Salvo size (number of weapons in the package) and Minimum Safe Delivery Height (e.g. '1000ft or

above') are shown. Refer to the second section of this chapter to find out how to change these settings.

All the waypoint types and their attributes are listed in the table below.

	Position	Altitude	Time	IAS/Mach	Target	Package	Headwind	Crosswind
Take-off	*		*				*	*
Turning	*	*	*	*				
Cap Start	*	*	*	*				
Cap End	*	*	*	*				
Initial	*	*	*	*				
Target	*	*	*	*	*	*		
Approach	*	*	*	*			*	*

Reading the Flightplan and Waypoint Data

Clicking on the Map Screen button marked 'Flightplan' brings up the Flightplan Window. This window breaks down into three horizontal strips. The top strip (the Tool Strip) contains buttons to call up sub-windows showing individual waypoint data, a Summary or a Profile (side view) of the flightplan, or to split and reformate waypoints when planning for multi-aircraft missions. The middle strip (the Waypoint Strip) shows a button corresponding to the label (A, B,.. X,.. F, G etc.) of each waypoint in the flightplan, allowing you to select one at a time, and at the lower left end buttons appear for inserting and deleting waypoints when appropriate. The lowest strip, the Aircraft Strip, shows the mission number in the daily sequence, plus individual buttons for all the aircraft in the formation. Like the waypoints, the aircraft are distinguished by letters A, B, C, etc. If this seems confusing, don't blame us, it's standard RAF practice. Aircraft callsigns are determined simply by the mission number (starting again from 1 every day) and the phonetic alphabet equivalent of the aircraft's letter within the formation, e.g. 003Alpha, 003Bravo etc. The Formation Leader (you) is always aircraft A, which will be the only letter shown if this is a mission for a single aircraft.

Flightplan Window

While this window is on-screen, clicking on the map with the LEFT mouse button has the effect of placing a new waypoint at the mouse position, so be careful. If you do accidentally create a new waypoint, just click ONCE on the 'Delete' button in the bottom row of the Flightplan window before you do anything else.

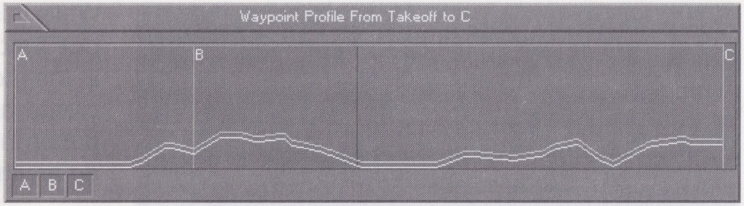
Select a zoom level of 2x or 3x and if it's not already highlighted, click once on the Waypoint Strip button labelled A. This will select waypoint A, highlight the button, and if the waypoint is off-screen the map will automatically be re-centred and re-drawn to show it. You can also select any waypoint and highlight its Waypoint Strip button by left clicking inside the waypoint symbol on the map.

Now click once on the Waypoint button in the ToolStrip. An additional window, the Waypoint Window, will appear, giving detailed data for the selected waypoint, showing all the attributes appropriate for its type. You can also call up this window by double-clicking (clicking twice in quick succession) on the Waypoint Strip button or the map symbol. Since this is a Take-off Point, the Time given will be your planned take-off time. If you select Waypoint B, then C and so on, the Waypoint window will remain on screen, displaying data for each of the waypoints in turn. This way you can step through the entire flightplan quickly and easily, reviewing the data for each waypoint and seeing it on the map, at any zoom level you wish to select. You can dismiss or drag the Flightplan window or the Waypoint window using the close box and the title bar, but remember that you can't create or drag waypoints unless the Flightplan Window is open. If you close the Flightplan Window, the Waypoint Window will automatically close as well.

Flightplan Summary Window

If you click on the 'Summary' button in the Flightplan window, you will be presented with a sub-window which summarises the whole flightplan in terms of times and actions. This may be compared with the Briefing description. It also shows fuel requirements, total flying time, etc.

Flightplan Profile Window



Profile Window

Clicking on the 'Profile' button in the Flightplan Window brings up the Profile Window - a wide shallow window showing all or part of your flightplan straightened out and viewed from the side, with the profile of the terrain beneath it. Any preset mission will always show a flightplan which is above ground at all points. Areas where the flightplan takes you underground will be shown as solid rectangles in a contrasting colour! Above the profile is a shallow horizontal bar which changes colour to show whether you are flying over Allied or Enemy territory at each point in the Profile.

Along the lower edge of the window is a row of buttons like the Waypoint Strip in the Flightplan window, one for every waypoint in the current flightplan. The buttons for the waypoints define the section of your flightplan which will be shown in profile - the ones shown highlighted are currently visible in the Profile Window. A single mouse click on a button will extend or retract the left or right end of the highlighted strip (whichever is closer) to the selected button and waypoint. Double-clicking on a waypoint button will bring up a profile covering three waypoints only; the one you clicked on, and those on either side of it.

When you first call up this window or when you use the waypoint buttons to change the section of Profile in view, the lines representing your flightpath, the terrain below and the 'ownership' of that terrain will be drawn quite rapidly. Once these are complete, the flightplan section will be checked against known AA Threats, and vertical hatching will be shown wherever it intersects a threat circle. After this is done, another (usually broken) line will appear on the Profile display, drawn more slowly from left to right. This shows, for every point along the Profile section, the altitude above which you will probably be visible to known enemy ground radars - so obviously your flightplan should keep you below it wherever possible. The reason why the line appears slowly is quite simple - the line-of-sight calculations needed to show this data take a LOT of processing power, but they are performed as a 'background task' and will not prevent you from moving about the map, zooming in or out, dragging windows

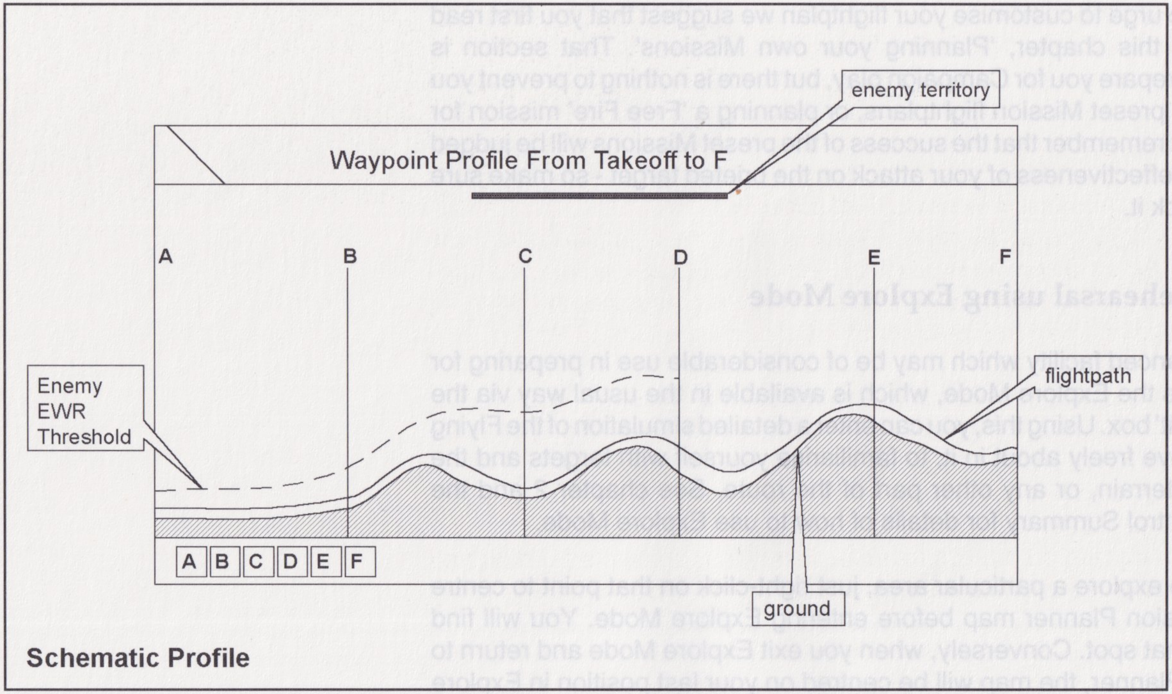


diagram 5.3

or performing any other function, though if you change the flightplan by placing, dragging or deleting waypoints the profile will need to redraw from scratch.

We would suggest that before flying any mission you step through all the waypoints in the flightplan, familiarising yourself with the route, the speeds, the targets and the attack modes at least. Another very good idea is to use the Key to turn on the AA Threat and EWR overlays before you do this. Though it may slow your display down, it will ensure that you're aware of where the hazards are, where you can afford to swing wide of your planned track, and where you absolutely must stick to it to avoid the enemy's defences.

If you feel the urge to customise your flightplan we suggest that you first read Section 2 of this chapter, 'Planning your own Missions'. That section is intended to prepare you for Campaign play, but there is nothing to prevent you from revising preset Mission flightplans, or planning a 'Free Fire' mission for yourself. Just remember that the success of the preset Missions will be judged solely by the effectiveness of your attack on the briefed target - so make sure that you attack it.

Mission Rehearsal using Explore Mode

Another advanced facility which may be of considerable use in preparing for the mission is the Explore Mode, which is available in the usual way via the 'Options../Exit' box. Using this, you can enter a detailed simulation of the Flying Area and move freely about in it, to familiarise yourself with targets and the surrounding terrain, or any other part of the route. See chapter 2 and the separate Control Summary for details of how to use Explore Mode.

If you wish to explore a particular area, just right-click on that point to centre it on the Mission Planner map before entering Explore Mode. You will find yourself on that spot. Conversely, when you exit Explore Mode and return to the Mission Planner, the map will be centred on your last position in Explore Mode, so cross-referencing between map and simulation is easy and convenient.

Met. Report

Before taking off, click on the Map Screen Button marked 'Met. Report'. This will open a window to give you a meteorological report, telling you about wind strength/direction and visibility conditions. For Simulator missions, some of these weather characteristics can be changed.

Wind
Shows bearing in degrees (the direction the wind is blowing FROM). This can never be changed. Wind Speed is given in knots. For Simulator missions, you

can select any one of a range of windspeeds by clicking repeatedly on the Cycle button beside the text. Outside the Simulator, the Cycle button will not appear, and the wind strength is not optional.

Visibility
Four visibility conditions are possible; Light Cloud Only, Overcast, Fog and Thick Fog. Overcast is a thick continuous layer of cloud. When there is Fog, there will always be an overcast as well. In the Simulator you can select any of these four conditions by using the Cycle button beside the text. Cloud Base and Tops figures are also shown in feet, and these cannot be changed.

Effects of Weather on the Mission

Wind
This will mainly affect the length of your take-off and landing run, and the difficulty of your approach. We've already discussed these problems in the Advanced Flying Training chapter.

The wind will rarely be so obliging as to blow directly along the runway available, so the idea is to take off and land in a direction which gives you a head-wind component rather than a tail-wind component. If you call up the Waypoint window for the Take-off or Approach Waypoints, you will see that the data for these waypoint types includes Head (or Tail) wind and Cross-wind speeds. Any sensible arrangement of waypoint B (which governs take-off direction) and the Approach Point (which determines landing direction) will show a Head-wind rather than a Tail-wind. The strength of the Cross-wind component will largely determine the difficulty of the landing. Preset missions will always set up take-off and landing directions to take account of these factors, but be careful if you start modifying the flightplan.

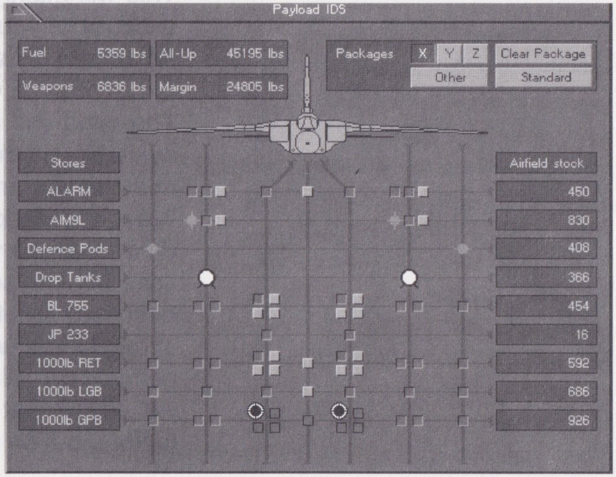
Cloud
Obviously you can't see through thick cloud, but neither can an infra-red sensor or most lasers. This may degrade or utterly destroy the performance of heat-seeking missiles, but it will also defeat your TIALD (Thermal Imaging and Laser Designator) cameras. Since laser-guided bomb attacks can only be

made using TIALD to designate the target, TIALD must be able to see the target if the attack is to succeed. Because you need to fly at about 23000' to give TIALD a wide enough field of view to track a target throughout an attack, this just can't be done if there's an overcast layer.

Finally, the Stores Loading Check
When you are satisfied that you understand the briefing, the flightplan, and any other relevant data, the last thing you must do is to verify that the aircraft is loaded with the correct weapons for the planned targets, add any defensive weapons desired (limited by weight and availability), and decide how much extra fuel you wish to carry. If a margin is available, or your targets cannot be planned, you can use the Payload Window to load weapons for attacks on targets-of-opportunity.

The Payload Window

The Payload window can be called up at any time by clicking on the Map Screen Button marked 'Payload' This displays in diagrammatic form all possible external stores and the aircraft hardpoints which can carry them, plus an indication of the fuel load, the total aircraft weight and the weight margin available. The ammunition tanks for your internal cannon will always be full at take-off, holding 180 rounds per gun.



Payload Window

For IDS aircraft, four buttons on this window allow you to view and manipulate any one of the three possible weapon Packages, or the remaining (non-ground attack) stores. The buttons for weapon packages loaded for planned attacks will show 'X', 'Y' or 'Z'. The contents of these packages cannot be changed except by changing the mission plan. If a package is empty or loaded for targets-of-opportunity, the button will show a dash ("-"). The 'Other' button displays external stores which are not part of any weapon Package, like drop tanks, AIM9Ls and defensive pods, and allows you to load or unload them.

ADV aircraft do not carry ground attack weapons, but can carry Sky Flash, which the IDS cannot, so the Payload screen for an ADV mission will show far fewer options, and there is no need to distinguish between packages.

Stores (weapons or other external loads) are listed down the left-hand side of the Payload window, with a line running horizontally to the right from each beneath the aircraft diagram. At the right-hand end of the line is a panel showing the number left in stock at your airfield.

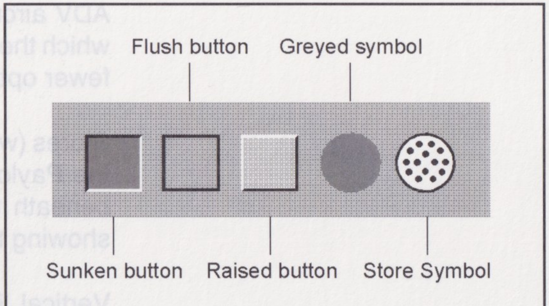
Vertical lines descend from the aircraft diagram at the top of the window representing the hardpoints to which stores can be attached. Where the vertical line from a hardpoint meets the horizontal line from a store, a symbol or a group of symbols may be shown, which we explain below. If no symbol is shown where the lines meet, then it means that the store is not compatible with the hardpoint. Each symbol means that one store can be fitted at this location. Where more than one symbol is shown at a junction, this means that either there is more than one hardpoint there and/or a carrier can be fitted to attach more than one store. Both of these cases apply to the left and right belly hardpoints, where up to four of many stores can be fitted - there are two hardpoints and each can be fitted with a double carrier.

Store/Hardpoint Symbology

Symbol	Meaning
Store symbol	A store in the current package (selected by clicking on a Package button) is fitted at this point.
Greyed symbol	A store in a different package (not the currently selected one) is fitted at this point.
Raised button	This point is available for this store within the current package

Flush button — This point is available for this store, but not within the current package. This is either because the type of store is inappropriate (e.g. drop tank in a ground attack package) or because it would violate the rule that each ground attack package must contain only one type of store.

Sunken button — It would be possible to fit this store to this point, but only if you unload something else.



Schematic of Payload Symbology

diagram 5.4

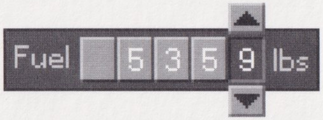
If a target-of-opportunity package (or the 'Other' package) is selected, stores may be loaded or unloaded by placing the mouse pointer on a Raised Button or a Store symbol and clicking with the left button. None of the other symbols will respond if you click on them.

Two other buttons appear at the upper right of this window, under the Package selection buttons. These are marked 'Standard' and 'Clear Package'. Clicking on the 'Standard' button will set up a load that consists of weapon packages for planned targets, plus drop tanks as appropriate, the defensive pods and 2 AIM9L. All other stores will be removed. When you first call up the Payload window after loading or creating a mission, the aircraft will be loaded exactly the way the Standard button would do it.

The 'Clear Package' button will only be active if the currently selected package is NOT 'X', 'Y' or 'Z'. Clicking on this button will unload all stores in the currently selected package, except for external tanks if these are essential for the planned mission.

Weight and Fuel

At the upper left corner of the screen figures are shown for All-up Weight (aircraft plus all fuel and stores), Stores Weight (excluding fuel in drop tanks), Fuel Weight (including fuel in drop tanks), and Weight Margin, which is the difference between All-up Weight and Maximum Take-Off Weight (MTOW). All of these weight figures are passive displays except for Fuel Weight, which can be used to load or unload fuel.



Fuel Weight Display

Whenever a mission flightplan is loaded, created or changed, a minimum fuel requirement is automatically calculated for the distances and speeds specified, plus a fixed margin of 1500 kg. (3300 lbs.). This calculated minimum fuel weight will be shown as already loaded when you first open the Payload Window. If more fuel is required for the mission than the internal tanks can hold, then external tanks will be shown as fitted. If the external tanks are fitted then they will always be full, and internal fuel will always be topped up to maximum as well.

When external tanks are NOT fitted, you can change your internal fuel loading by means of the Fuel Weight display. Click on the digit of the Fuel Weight figure which you wish to change. This will cause buttons showing arrow symbols to appear below and above the digit. Click on the arrows to change the digit up or down. Click and hold down for rapid change. Digits above or below will be affected as the changing digit passes upwards through 9 or downwards through 0. To change a different digit, just click on that digit instead, and the arrow buttons will move over. The arrow buttons can be dismissed altogether by clicking a second time on the digit between them. Using the arrow buttons you can increase the fuel quantity up to the maximum internal fuel figure. If you want more, this can only be done by loading full external tanks (in the 'Other' package).

If you reduce the fuel load to below the calculated minimum requirement, a small window called the Problems Window will automatically appear on the screen. Many different messages can and will appear in the Problems Window when you start to plan your own missions, but this one will say something like 'ERROR: 001A - Not enough fuel for flightplan'. This means what it says: you have too little fuel to fly the flightplan, and you won't be allowed to take off until you've either loaded more fuel or replanned the route to reduce the fuel requirement. For more detail on the Problems Window, see the second section of this chapter.

What to load?

The 'Standard' option, will always load certain items if there are hardpoints to take them. For the IDS these are the defensive pods (chaff and flare dispenser

on the starboard outer wing pylon, ECM pod on the port outer), and a pair of AIM9L for self-defence, one on each inner wing pylon. Other stores may be loaded in these places, but think hard before you leave the defensive pods at home. If you do, you will have NO chaff or flares or ECM! This does not apply to the Tornado ADV, because all these items are internal on that aircraft.

The AIM9L are more genuinely optional. Without them your only air-to-air weapon is the gun, but standard tactical doctrine for a Tornado IDS faced with an interceptor can be summed up in two words: Run away! On the other hand, this means that you immediately grant the enemy a 'mission kill' - you're still alive, but your mission is dead. The decision is up to you, but because the weight and drag of the AIM9L are comparatively small we would suggest that you carry them unless you definitely need the stores points for something else, like ALARM.

If you want to load these items for yourself, remember that you must click on the 'Other' package button first.

Another discretionary form of defensive armament (though sometimes these will be the weapons specified for your planned attack) would be ALARM anti-radar missiles to use in Direct mode against SAM or AAA threats in your way, but these are fairly heavy, and you may not have suitable hardpoints free to carry them. If you do decide you want to take some, first click on any package button showing '-' to assign them to a package which is currently unused.

If there are free Packages, free stores points and a sufficient weight margin, you may if you wish load extra ground attack weapons for unplanned targets - Targets of Opportunity. Just click on a Package button showing '-', and add the weapons you want. All weapons in one Package must be of the same type. The delivery mode for such a package will automatically be set to Manual delivery, or its nearest equivalent for the weapon concerned, but it can be changed in the air using the Stores Management Display. See the Weapons Conversion chapter and/or the Aircrew Notes section on the Navigator's Cockpit Layout for details of how to do this.

Keep it in mind that a heavily loaded aircraft will handle more sluggishly and fly more slowly than an aircraft with a lighter load. An aircraft loaded near its maximum take-off weight will need careful, smooth flying to avoid stalling when flying at low speeds. Sometimes a maximum load is unavoidable, but don't make a habit of taking all of your weight margin as extra fuel or weapons.

Starting the Mission

When you are satisfied that you have absorbed all the necessary information, and that the aircraft is suitably loaded for the mission, you can click on the Map Screen Button labelled 'Take-off' After a brief pause to download the flightplan to your aircraft, you will find yourself in the cockpit, on the runway, with immediate clearance to take off. Before you do so, be sure you have worked through the 'Taking Off' section in the Elementary Flying Training chapter, or at the very least consulted the checklist given in the Aircrew Notes.

Final Exercises

Now that you can read the flightplan before you take off, we suggest that you try out the Bombing Range exercises available under the Training option. Remember that this is live flying, not like the Simulator. You can't arrange for the aircraft to bounce off the ground, you must fly the aircraft at actual weight, and you can't just blow up or shoot down anything that takes your fancy. The Debrief for the Bombing range exercises will include a score for accuracy (see the Debrief chapter for details).

Once you've done these, try the Training exercises tagged 'OCU' (Operational Conversion Unit), which simulate actual missions apart from enemy fire, then go back to the Simulator, where another more difficult and realistic set of OCU missions (plus air combat exercises) are available. Switch on enemy activity and as much realism as you can handle, then try these out against a simulated enemy, in all weathers.

We cover how to use AFDS Track mode to follow an IDS flightplan in the Advanced Flying Training chapter. For an ADV flightplan which may contain a CAP pattern, it's very similar. Just take off and engage Track mode. The AFDS will fly you to the CAP Start and feed you into the pattern. If left under AFDS control the aircraft will loop between CAP Start and CAP End points until it runs out of fuel. You can break out of the rut by either disengaging the AFDS, or using the 'Skip to next waypoint' key to advance the selected waypoint past the CAP End point. There's a Simulator OCU CAP mission which lets you try this out.

When you can fly and survive the OCU missions against the worst the simulator can throw at you, you're good enough to take your chances in Combat. Start with the single Mission options. You have three different War Zones to fight over, so it'll take you some time to exhaust all these possibilities. Some of the missions are solo exercises, some of them involve coordinating with other aircraft - remember that timekeeping is just as important as accuracy. When you think that you're getting the hang of it and you understand the tactical problems, move on to the next section and put your own ideas into practice.

SECTION 2 - PLANNING YOUR OWN MISSIONS

2a - 'FREE FIRE' and LEVEL 1 CAMPAIGNS

This section assumes that you have read and understood all the instructions on basic use of the Mission Planner given in the preceding section. There are several ways to get started on planning missions for yourself. You can try editing some of the Simulator Missions for practice, and then go on to Combat, or you can select 'Mission' from the 'Combat' screen, followed by either of the Missions titled 'Free Fire' from the Selection Menu. When you arrive at the Mission Planner for a 'Free Fire' mission there will be no preset mission plan at all, and it's up to you to select a target, a patrol station or other objective and create a flightplan. Apart from the need to define your own objective and

flightplan, a ‘Free Fire’ mission works exactly like any other single mission, and is entirely self-contained.

The Campaign option is the next step up, providing a connected series of missions set in a military situation which evolves over time. If you choose ‘Campaign’ on the ‘Combat ‘ screen, and one of the Level 1 Campaign scenarios you will see a bare outline of a mission which simply specifies an objective, rather than a complete flightplan. This outline is your Task for the next mission, and you must do all the detailed planning, then fly it. When (and if) you return from that mission your commander will present you with a new Task to plan and fly. The Campaign will last for as many missions as it takes to accomplish the Campaign objectives, or to lose the war, or until a stalemate is reached. When you need a break, you can exit from the Mission Planner to the Mission Selection Screen and save the current situation to reload and continue later.

IDS missions in a campaign will have a variety of aims. They might be directed at reducing the enemy’s air-power (Counter-Air Operations), denying him the routes he needs to supply or move his ground forces (Interdiction Operations), destroying other vital enemy installations (Attack Operations), or beating down AA threats to clear the way for further strikes (Defence Suppression). You may also be called upon to provide Close Air Support, attacking enemy ground forces actually on the battlefield. This will only happen if your side is in a truly desperate situation - and if it does, your chances of survival are not good. The best way to avoid this is to succeed in your primary missions.

After each mission, the Task for the next will reflect your degree of success so far, and its effect on the military situation on the ground.

At this level you don’t have to decide what to hit or when. The Task specifies the time and the target, the nature of the target dictates the choice of weapon, but it is up to you to decide how to reach the target, attack it and return with the maximum probability of success and the minimum risk.

If you are trying out the 'Free Fire' Missions, you can choose anything on the map as your target and you can land at any airfield you like, provided it's allied, but you will always start at the same airfield. On the map you'll see that the Take-off waypoint A is already set, marking your position.

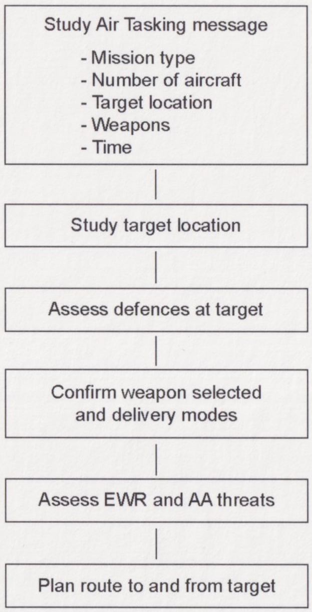
Read, or suffer the consequences...

This is not a threat, it's a friendly warning. This section aims to cover all you need to know to create flightplans, though we can only give you general advice on tactics. Some of this material is relevant to Campaign play, some is only relevant to 'Free Fire' missions. Whichever of these options you plan to try out, read all of this section first - once you start creating and editing missions you have enough freedom of action to screw up in a big way! It's vital that you understand what you're doing - you'll soon discover that you won't be allowed to take off if your flightplan doesn't make sense.

Turning a Task into a Flightplan

When you select a Campaign scenario on the Mission Selection Screen, instead of the Briefing you would expect for a single mission you will see a summary describing the military situation at the time the Campaign starts. The title of the Campaign scenario itself should give you some clue as to what to expect. When you Commit and move to the Mission Planner, two differences should be seen: a) there is a flightplan laid out, but it's just a skeleton, and b) the Map Screen Button which used to say 'Briefing' is now titled 'Task'.

Click on the Task button to see the Air Tasking Message - these are your orders. They will describe the type of mission in terms of role (Attack, Interdict, Counter-Air etc.), the type and callsigns of the aircraft taking part, the position and nature of the target(s), the type of weapon to be used and the time for the attack. Times may be specified as TOT (Time On Target), which must be achieved in order to coordinate with other activity, or as NLT (Not Later Than), which leaves you with some discretion.



Planning Your Flight

diagram 5.5

In Level One Campaigns, you will only need to create a flightplan for yourself, and the following paragraphs deal mainly with that situation, deferring the problems of multi-aircraft mission planning (Level Two Campaigns) till later.

Problems, Warnings and Errors

When you first see the skeleton flightplan of a new Task on the Mission Planner map, you'll often notice a small window without a close box, titled 'Problems'. This appears because the Task outline as it stands is not a viable flightplan, and the planning support systems are automatically alerting you to the fact.

The planning systems apply a set of rules to any flightplan to detect unreasonable situations such as unflyable course changes, impossible or improbable timings and speeds, or Initial Points too close to the target. When a flightplan bends or breaks these rules, the Problems window will automatically appear with a list of messages. These messages will start with either 'ERROR' for a problem which must be fixed before you take off, or 'WARNING' when the problem is not so serious as to completely invalidate the flightplan. You can either tackle these problems immediately or leave them until later, but you will not be permitted to download the flightplan and take off while any ERROR message appears in the list. Every message is tagged with the callsign (mission number plus letter) of the aircraft to which it applies; 003 A for example. This is done so that when you're planning multi-aircraft missions, you know which message applies to which aircraft.

Setting and Moving Waypoints

If you are planning a 'Free Fire' mission there will be only one waypoint on the map when you enter the Mission Planner - the Take-off Point, where you and your aircraft are based. You will have to lay down all the other waypoints for the mission yourself. If you are starting a Campaign, an IDS Task outline will usually preset Target Waypoint(s), and an ADV Task will usually preset a CAP point, depending on the nature of the mission, plus an Approach Point. You will generally create your flightplan by inserting extra waypoints between the ones you are given, and then dragging them into position. Both operations are quite straightforward, and complications only arise when you place waypoints too

close together, so for your initial experiments it is best if you keep waypoints spaced well apart.

In order to start placing or moving waypoints you must first click on the Map Screen Button labelled 'Flightplan', thus opening the Flightplan window. Remember that a flightplan may have up to 15 waypoints, but no more. When the limit is reached, the system will refuse to create any more.

Placing Waypoints

Clicking anywhere on the map with the LEFT mouse button will place a new waypoint at that point, adding it to the end of your current flightplan. The new waypoint will be a Turning Point by default unless it is placed in the ILS coverage of an allied airfield, in which case it will be created as an Approach Point.

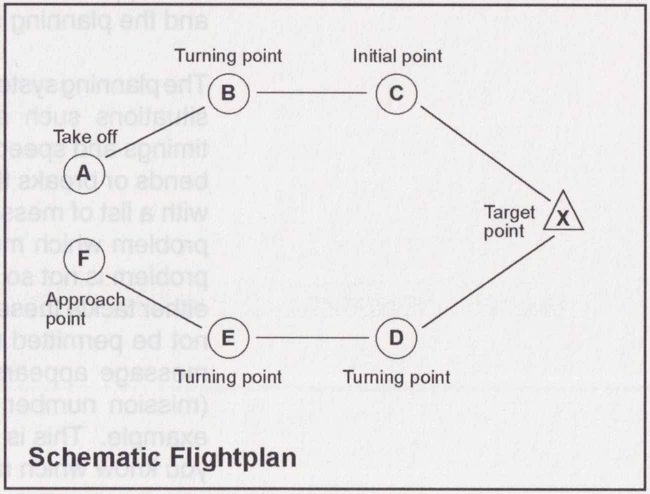


diagram 5.6

Dragging Waypoints

Place the mouse pointer crosshair on the symbol of the waypoint you wish to move and hold down the LEFT mouse button. While you hold the button down you may drag the waypoint about the map by moving the mouse. 'Rubber Lines' will be drawn to show the new legs to and from the waypoint affected. When you release the mouse button the waypoint is 'dropped' in its new position, and the legs to and from will be redrawn, together with the curve of the turn following the waypoint. Depending on how far you moved the waypoint, other legs and curves may also be affected. The smoothness or otherwise of the curve drawn can be adjusted on the Preferences screen.

Note that dragging a waypoint also selects it (see below). Dragging a waypoint from place to place will not change its Type unless it enters or leaves the ILS coverage of an Allied airfield. A Turning Point dragged into ILS coverage can become an Approach Point, and an Approach Point dragged out of ILS coverage reverts to a plain Turning Point.

Selecting Waypoints

A waypoint must be selected before certain operations can be performed upon it. The letter of the selected waypoint is highlighted in the Flightplan Window. Waypoints may be selected either by clicking on the appropriate letter in the Flightplan Window, or by clicking inside the appropriate waypoint symbol on the map.

Deleting Waypoints

The Delete button is not shown in the Waypoint Strip of the Flightplan Window unless it's permissible to delete the selected waypoint. Clicking on this button deletes the selected waypoint, as you'd expect, and causes waypoints later in the flightplan to be relabelled as necessary. Earlier and later curves and legs may be affected by the deletion. Waypoint A can never be deleted. When working with a flightplan for multiple aircraft, only formation waypoints may be deleted.

Inserting Waypoints

The Insert button is not shown in the Waypoint Strip of the Flightplan Window unless it's possible to insert a new waypoint BEFORE the currently selected one. New waypoints are inserted halfway between existing ones, and must be dragged to their desired positions. Waypoints after the insertion point will be relabelled as necessary. Waypoints cannot be inserted if all 15 available waypoints are already used. When working with a flightplan for multiple aircraft, insertions can only be made in legs common to all aircraft in the formation.

Turning Circles

As you should already know, the planning system plots a curve after each waypoint, leading into the straight leg towards the next. The radius of the curve is governed by the Speed set for the adjacent waypoint and the control authority of the AFDS system: the faster the speed, the wider the turn.

When you are dragging waypoints about, the legs to and from the waypoint are drawn as 'rubber lines', but the curve is not drawn (this is to speed up the screen redraw). However, the turning circle calculations are still performed,

and the lengths and directions of the legs are accurate. Because the direction INTO the next waypoint is changed, the curve out of that waypoint will change also, affecting the direction into the next, and so on. The effects will ripple on through the flightplan for a greater or lesser distance depending on how large a change you made, but you will not see the ripple effect until you drop the waypoint in place and the legs affected are redrawn.

For this reason, if you wish to control the precise direction of more than one leg in a flightplan (e.g. for a JP.233 attack run or an approach for landing) it is best to lay out all the waypoints first, then precisely place the Target Waypoint(s), select weapon(s) and delivery mode(s), set any fixed Speeds (and/or Times) and only then to work through the flightplan in order from start to finish dragging waypoints to set direction, so that changes rippling forward affect only the legs which you have not yet adjusted.

Two kinds of problem can arise when you place two waypoints too close together. The first of these problems can affect any pair of waypoints, and happens when the second waypoint is INSIDE the diameter of the turning circle curve from the first. *Diagram 5.7* shows that this means it is quite impossible for the aircraft ever to reach the second waypoint by turning towards it - instead it will circle until you use the Next Waypoint key to skip the offending waypoint. Not only will this type of error be flagged in the Problems Window (e.g. 'WARNING: 001A - C too close to B'), but the curve will not be drawn and the preceding and following legs will meet at the waypoint as straight lines.

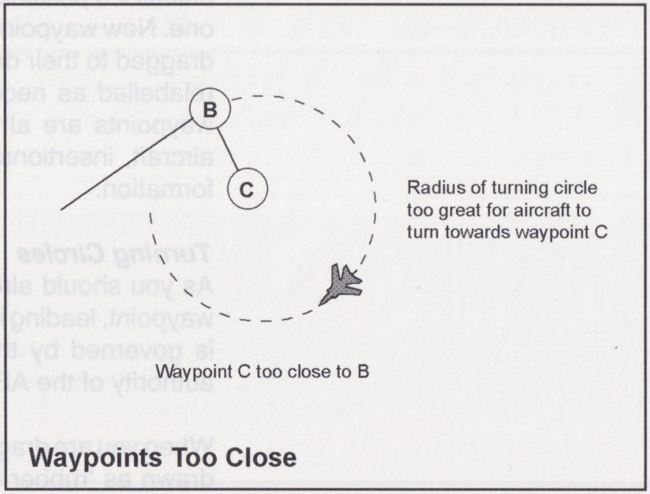


diagram 5.7

The second type of problem affects only Initial Points and Targets. The planning system calculates how far back from the target the weapon will be released, and demands that you must have time to line up on a straight attack run before you reach the release point (or the pull-up point for a Loft attack). This type of problem will be flagged in the Problems Window (e.g. 'WARNING: 002A - IP too close to X').

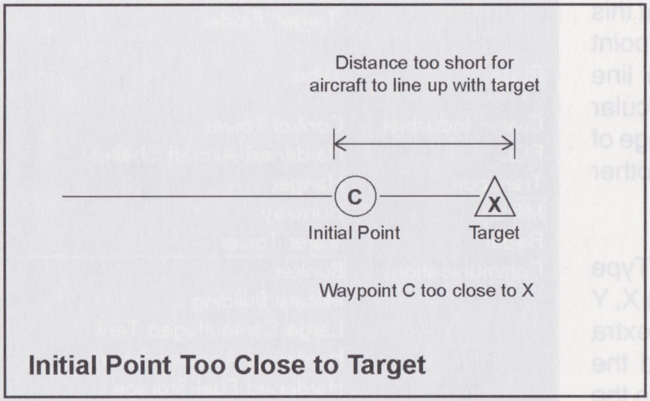


diagram 5.8

Target Waypoints and Attacks

We've now covered the procedure for placing Turning (or Approach) waypoints, but position is only one of the attributes of a waypoint. Many of the other attributes (Time, Speed, Altitude etc.) can also be adjusted as necessary, and the Target Waypoint is the type which most often requires tinkering of this sort, as well as the setting up of the weapons Package for the attack.

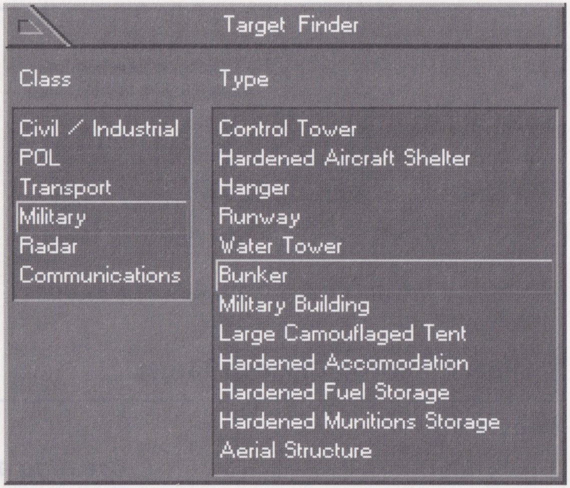
Because it's the most critical type of waypoint, we'll cover its set-up in detail, though you won't need to perform this entire operation from scratch unless you are planning a 'Free Fire' mission or playing at Command level.

Creating and Placing a Target Waypoint (IDS only)

The accurate placement of a Target Waypoint is obviously critical. The first problem is to identify the target on the map. Assuming that you know what type of target you want to hit and roughly where it is, centre the map on the approximate position and place a standard Turning Point waypoint there. There are two ways of doing this: one is to call up the Point Data Window and explore with the mouse pointer, the other is to use the Target Finder, which can also be useful for choosing targets in the first place.

Click on the Map Screen Button labelled 'Targets', which calls up a window showing two lists. Click on an item in the left list to select a category of target (Military, Transport etc.). The right list will change to display a list of individual types of target in the selected category (e.g. Hangar, Hardened Munitions Store etc.). Click on the type which describes your target. Every target of that type on the map will now be marked by the Category Flag symbol, helping you pick out your intended target from other buildings in the same area. Category Flag symbols will be shown on the map while the Target Finder window is open, regardless of whether or not Category Flags are turned on in the Key. When you close the Target Finder window, the Category Flag symbols will disappear unless they are enabled by the Key.

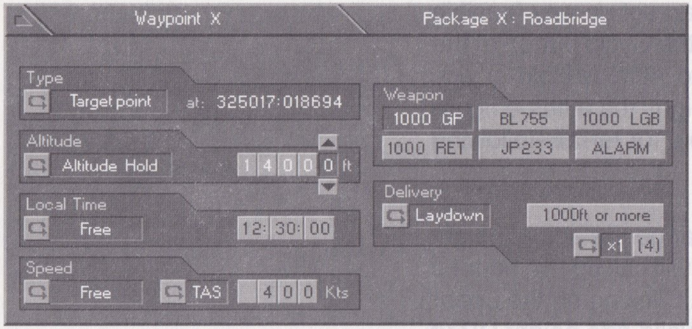
Drag your intended Target waypoint (still a Turning Point at this stage) to the target and drop it there. Now call up the Waypoint Window if it isn't already open. At the left end of the line displaying the waypoint Type is a button showing a small circular symbol. This is a Cycle button, used to cycle through a range of alternative options. As you can see, there are many other buttons of this type in a Waypoint Window.



Target Finder Window

Click once on the Type Cycle button. The waypoint Type changes from Turning Point to Target, the label changes to X, Y or Z, the Waypoint Window expands and acquires the extra displays necessary to define the weapon Package, and the waypoint symbol on the map changes shape and 'snaps' to the intended target. Whenever you change a Turning Point into a Target waypoint, the waypoint will snap to the exact position of the nearest object. If Category Flag display is enabled, it will snap to the nearest flagged object. The 'snapping' feature can be disabled by holding down the Alt key while dragging the Target Waypoint. The Turning Point before the Target will automatically change to an Initial Point.

The planning systems will also select a default weapon Package based on the type of Target, but if you like you may change this. To select a Weapon type just click on the desired button in the Weapon display. If the weapon type has more than one possible delivery mode you may choose from the available options by clicking repeatedly on the Cycle button at the left of the Delivery display. At the right of the Delivery display is the Safety Height Button; clicking on this sets the waypoint Altitude to the minimum safe height. Below this is the Salvo Size display, showing how many weapons there are in the Package. The Cycle button beside it can be used to select a size of 1, 2 or 4 weapons, depending on the type. The button to the right shows the recommended salvo size for the recommended weapon, and clicking on this will set that figure.



Target Waypoint Window

Setting up a CAP Station (ADV only)

The 'typical' ADV Combat Air Patrol mission involves taking off, flying to a given position and altitude, and then flying round and round in a 'racetrack' pattern waiting to intercept enemy aircraft. In order to set up a CAP mission, create a skeleton flightplan (if it's not provided) and place a Turning point roughly where you want each end of your racetrack pattern to be. Space them fairly well apart to start with. Now select the first of these two waypoints and call up the Waypoint Window. Click on the Cycle button for the waypoint Type, and it will change to 'CAP Start'. This will automatically convert the next Turning Point into a 'CAP End', and you should see the leg between the two change into a circuit with rounded ends your CAP pattern.

Normal practice would be to line the racetrack up so that the long axis points in the general direction of the enemy. This means that on one of the two 'straights' you're pointing your radar (set for maximum range) in the direction from which you expect business, on the other you're mainly watching your Radar Warning Receiver, and at the ends you sweep the airspace on either side of the pattern.

Once a CAP pattern is set in a flightplan you will not be allowed to change the types of any other waypoints, though you can still insert, delete or drag points as usual. You can still go back to the CAP Start point and change it back to a Turning Point, though. This will also change the End point and give each Turning Point an active Type Cycle button again. Times of waypoints after a CAP pattern are obviously fairly meaningless - you don't know how long you'll be waiting there.

Altitude

For normal air-to-ground operations the Altitude Authority Mode shows 'Ride Height' and the value set is 200 (feet), so that if the aircraft is under AFDS Track mode control it will fly these legs terrain-following at 200 feet. We have just mentioned the button which copies the Minimum Safe Height for the selected

weapon type into the Altitude figure, but in fact you can set up any feasible combination of Authority Mode and value. Clicking on the Cycle button at the left of the display changes the mode from 'Ride Height' to 'Altitude Hold' or vice versa. When changing from 'Altitude Hold' to 'Ride Height' the altitude figure will 'snap' to the nearest valid setting which is available for terrain-following (200, 300, 400, 500, 750, 1000 or 1500 feet).

If you have selected 'Ride Height' and you want to change the actual height value, click on the button showing the value itself. This will call up two buttons showing arrows, one above and one below the figure. Clicking on the upper arrow button will change the height figure to the next valid ride height UP (if any), and clicking on the lower arrow button will change to the next valid height DOWN. Clicking on either button and holding the mouse button down will cause the figure to change rapidly. Clicking again on the figure itself will dismiss the arrow buttons.

If you select 'Altitude Hold' as the Altitude Authority Mode, each digit of the altitude figure will appear as a separate button. Clicking on any of these will call up arrow buttons to change one digit at a time up or down. Note that a 'carry' will affect the next digit to the left or right as you change any one digit up past 9 or down past 0. If you're planning legs set for Altitude Hold, don't forget to check the Flightplan Profile Window to make sure that you're not proposing to fly through hills.

The planning system will check your altitude on the Attack run against the Minimum Safe Height for weapon release, and issue a WARNING if it's set too low. If you're going to fly the attack run manually you can ignore the warning and run in as low as you like provided that you're at a safe height (or horizontal distance) by the time your bombs explode.

Times and Speeds

If you've been trying out these procedures as you go, you may have noticed that when you change a waypoint's Type from Turning Point to Target, the Speed setting for the Target Waypoint changes to a higher figure, depending upon the weapon type selected.

The system uses two default values for speed; 420 knots as a standard cruise, and 550 knots as a standard speed for attack runs; and it will normally calculate waypoint times using these values. If you wish, however, you may set any feasible speed value you want for any leg, and if you do the Speed status will change from 'Free' to 'Fixed'. 'Fixed' status means that the planning systems will juggle other times and speeds which have 'Free' status as much as necessary in order to ensure that you can fly your attack run at this speed and still maintain your timetable.

If a Time-On-Target (TOT) is specified in the Tasking Message, it would be normal for the time at the Target waypoint to be set as 'Fixed' too. Regardless of what the Tasking Message specifies this should be mandatory if more than one aircraft is involved in the operation, though each aircraft's TOT may be different by a few seconds. Times and Speeds are closely bound together, so it makes sense to deal with both at once.

Time and Speed status can be changed using the Cycle buttons at the left of their respective display lines, but it would be more common to change the actual Time or Speed value first, which will automatically change a 'Free' status to 'Fixed'.

Changing the Speed value is done just like changing the Altitude value, by clicking on a digit and then using the arrow buttons. Use the Cycle button to the left of the value to change the speed representation between Knots IAS and Mach Number, whichever is more convenient. The Time value is changed in a similar way, except that here there are buttons for hours, minutes and seconds rather than for the individual digits.

Time and Speed Problems

A waypoint's Time is the planned time of arrival (and/or departure) at that waypoint. The Speed is the average speed over the preceding leg of the flightplan which will get you there at that time. Speed at a waypoint is also used to calculate the radius of the turn onto the next leg, so you'd better wait till you're on the straight run to the next waypoint before you accelerate or decelerate. Calculating the Times and Speeds by hand and making them all fit together

would be very tedious, time-consuming and error-prone, so the planning systems will automatically recalculate and check all Times and Speeds every time a waypoint is created, moved or deleted. The system is very capable, it saves you a great deal of work, and it won't create impossible timetables unless you flatly order it to - and even then it will use the Problems Window to inform you that you are asking for the impossible or the unlikely.

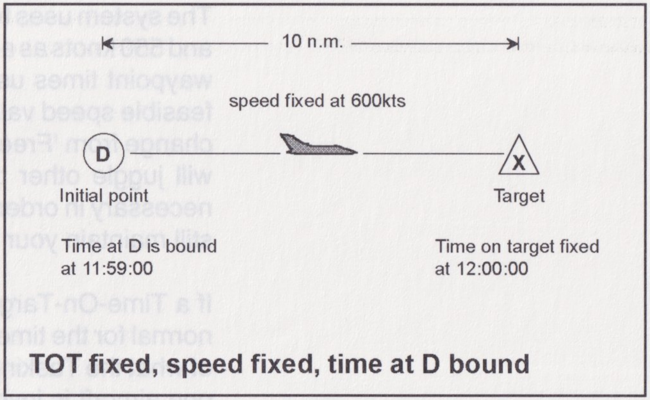


diagram 5.9

We've tried to make this system as intelligent and easy to use as possible, but the laws of physics impose a number of irksome restrictions, given that we're simulating a Tornado rather than a Time Machine. It's easy to be carried away by the possibilities of the scheduling system - and if you are, you run the risk of ending up in a straitjacket, one way or another. You need an appreciation of what's possible and what isn't.

Let's assume that we have a target (X) ten nautical miles away from its Initial Point (call it D). The Time at X is 12:00:00 Fixed, Speed is 600 Knots Fixed *(see diagram 5.9)*. If you were to look at the Waypoint data for D, you'd find the Time at D showing as 11:59:00 Bound, and you would be unable to change status or value directly, though the Time would change if you dragged D to a different position . What's going on?

The Speed of 600 knots for the leg D-X dictates exactly how long it should take to fly the distance from D to X: at 600 knots you'll cover the 10 nautical miles from D to X in 1 minute. That means that you MUST pass D at 11:59:00 - no other answer is possible unless you start allowing for variable speeds over the leg. That would open up a can of worms which we would prefer to keep firmly shut. That's why the Time status at D is 'Bound'.

There is another variant of the same problem. If you Fix the Times of two adjacent waypoints, the Speed for the leg between them (the one given for the second waypoint) becomes Bound; it is dictated absolutely by the Times and the distance between the waypoints.

The best way to avoid creating problems for yourself is to Fix Times and Speeds only when necessary - and most of the time it's not necessary. Under normal circumstances the only Time in a mission which needs to be Fixed is the Time-On-Target, and the only legs where Speed need be fixed are legs where you have no choice but to cross defended zones.

Tactics for Mission Planning

We've now covered the mechanics of manipulating waypoints in the Mission Planner, but the really important question is; what to do with them? What you should be trying to achieve is the most effective attack possible with the minimum risk. It's time to look at tactics.

Assuming that you know what your target is, you can either accept the weapons package which is given in the Tasking Order or selected automatically by the planning systems, or you can use your own judgement to find some alternative type of attack which will increase your accuracy or decrease your risk or ideally both. To make this sort of judgement for yourself you'll need to be familiar with all the weapons, their capabilities, their delivery modes and the sort of accuracy achievable with each. The best and safest way to acquire a feel for the subject is to practise intensively in the Simulator.

Assessing the risks, however, really requires practical live experience of trying to penetrate enemy territory, defend yourself and deliver attacks under fire. You'll have to acquire this experience for yourself, but we'll try to give you some idea of the questions you should be asking yourself:

Choosing the Axis of Attack
The direction in which you make your attack may largely determine its success, for several reasons. Your direction of approach should try to strike the best possible compromise between three demands which frequently conflict with one another:

1: The ideal Attack Run on a defended target is the one which overflies no AA threats and uses the terrain to mask you from the target defences until the last possible moment.

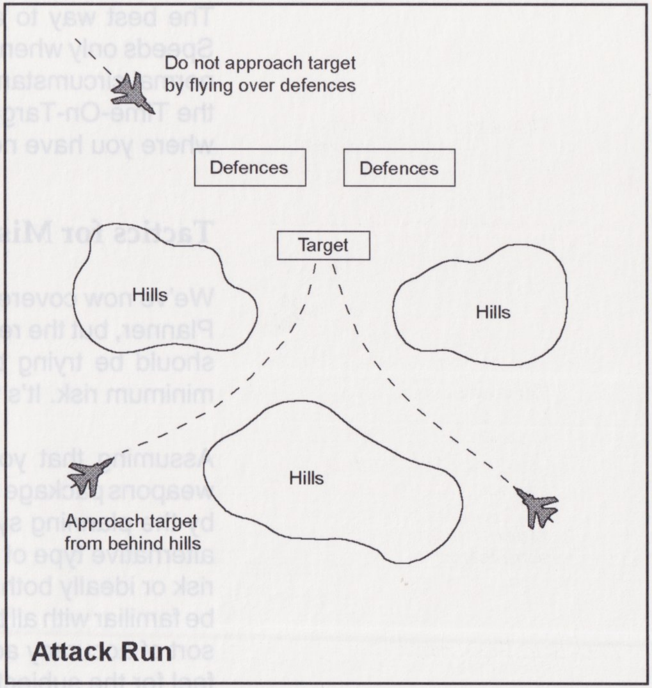


diagram 5.10

2: In any unguided bomb or dispenser attack, the salvo or the submunitions have the greatest probability of landing in an area or 'footprint' which is relatively long in your direction of flight and relatively narrow from side to side *(see diagram 5.11)*. The ideal Attack Run will exploit this effect to maximise the chance of destroying something worthwhile. The simplest example of this is a JP233 attack on a runway. If your Attack Run takes you over the runway along its length, or (even better) at a small angle to it, almost all of the submunitions will fall on the runway, making the maximum number of holes in it. If you make your attack at right angles across the runway, a much smaller proportion of the submunitions will fall on the runway itself, and most will be wasted. Military installations, especially airfields, are frequently laid out in such a way as to avoid concentrating too many targets in a straight line, but it will almost always be possible to identify good and bad directions for an attack.

3: The ideal Egress Run from a target is the one offering the fastest way back into cover, leading to the quickest safe exit from enemy territory.

Routing to and from the target area
Having set up the Target Waypoint and the waypoints immediately before and after it, the next thing to do is to construct the rst of your route from take-off to Initial Point, and then back to the airfield at which you intend to land. Creating the waypoints to do this is easy using the Insert button, and you can drag the resulting waypoints about the map at will. The problem is deciding where to put them. Here are some of the factors which should affect your decisions:

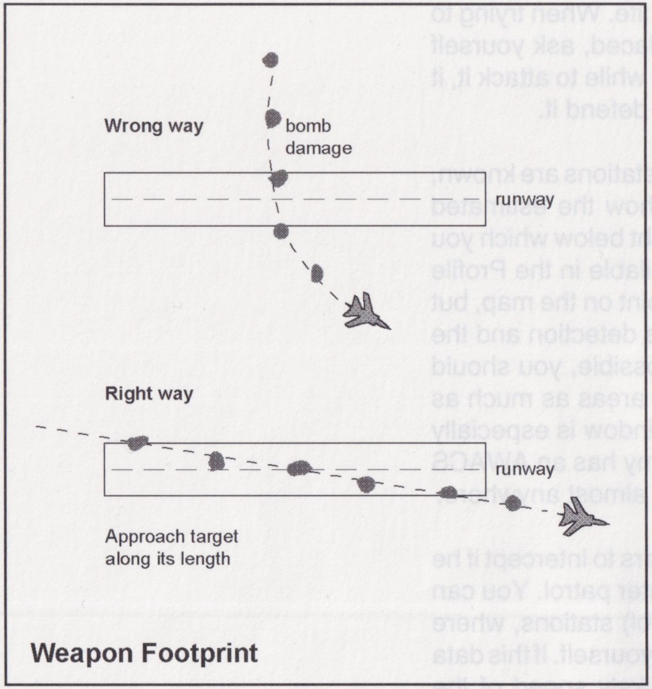


diagram 5.11

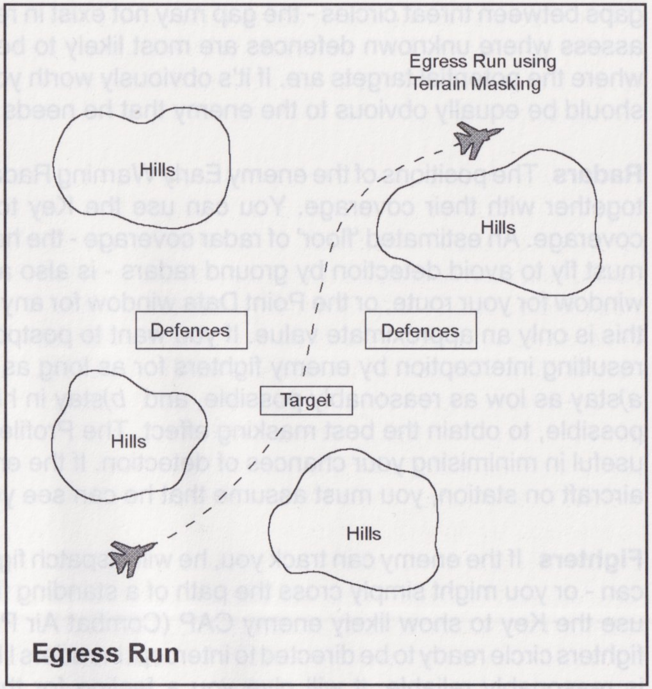


diagram 5.12

AA Threats: Many if not all of the enemy's AAA and SAM sites will be known, and also the effective ranges of the weapons there. It's obviously not a good idea to fly within range of these if you can avoid it. You can use the Key to command the display of the relevant threat circles, showing the areas to avoid. If at all possible you should also avoid any area where there is large-scale ground fighting in progress, or indeed any area where enemy ground forces are thought to be present in large numbers.

Remember that unless your intelligence is perfect, you don't know the position of every last threat, and the positions of the ones you do know about can't usually be given with absolute precision - the threats are mobile, and it's in the enemy's interests to move them about from time to time. Be wary of narrow

gaps between threat circles - the gap may not exist in real life. When trying to assess where unknown defences are most likely to be placed, ask yourself where the potential targets are. If it's obviously worth your while to attack it, it should be equally obvious to the enemy that he needs to defend it.

Radars The positions of the enemy Early Warning Radar stations are known, together with their coverage. You can use the Key to show the estimated coverage. An estimated 'floor' of radar coverage - the height below which you must fly to avoid detection by ground radars - is also available in the Profile window for your route, or the Point Data window for any point on the map, but this is only an approximate value. If you want to postpone detection and the resulting interception by enemy fighters for as long as possible, you should *a)*stay as low as reasonably possible, and *b)*stay in hilly areas as much as possible, to obtain the best masking effect. The Profile window is especially useful in minimising your chances of detection. If the enemy has an AWACS aircraft on station, you must assume that he can see you almost anywhere.

Fighters If the enemy can track you, he will dispatch fighters to intercept if he can - or you might simply cross the path of a standing fighter patrol. You can use the Key to show likely enemy CAP (Combat Air Patrol) stations, where fighters circle ready to be directed to intercept intruders like yourself. If this data is reasonably reliable, it will give you a feeling for the likely speed of the enemy's response if and when he detects you. More rarely, fighters might be scrambled from readiness on the ground to intercept you, but this gives a much slower response and is therefore less dangerous - unless the enemy saw you coming from a long way off!

Distance Flying at maximum weight, especially in enemy airspace, is to be avoided if at all possible. The length of your route, the load you carry, and the speeds at which you plan to fly will all influence your fuel requirement. Therefore the distance factor must be balanced against the others given above. The estimated fuel consumption for the flight is shown in the Analysis window.

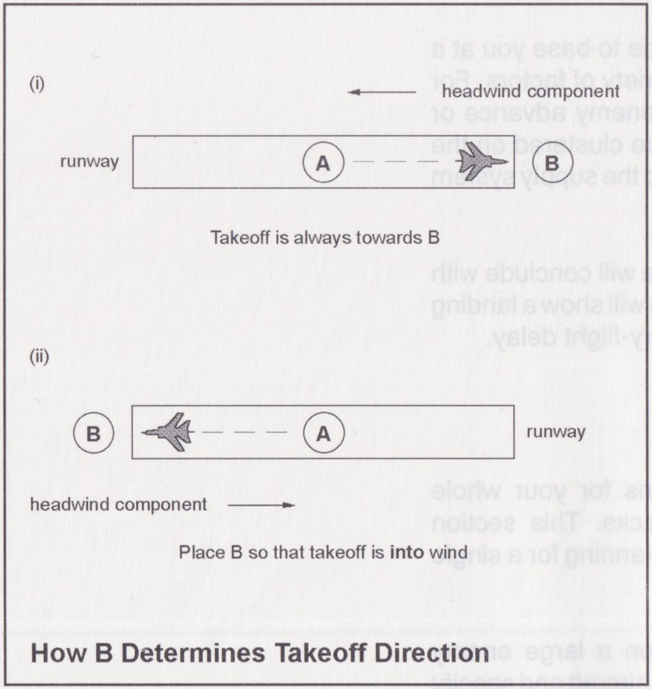


diagram 5.13

Selecting Take-off and Landing Direction

Call up the Met. Report and study the wind strength and direction. Now set up the first waypoint after take-off (inserting a new one if necessary) so that you will be taking off with a head-wind component. See *diagram 5.13* for an explanation of how the direction of the first leg dictates which runway you will be set up to use.

As for landing; the Approach point specified in the Task will normally be set up to land you into wind, and you will not need to change this unless you wish to land somewhere else (see below).

Landing away from base

If the distance you have to fly becomes excessive, you might consider planning to land at another allied airfield. This is always possible, as in the case of diversion for an emergency landing. The only penalty for this is that during a Campaign the time required for the ferry flight back to your operating base will delay the start of your next mission. When you return to the Mission Planner your aircraft will be shown at its base airfield - the time for the ferry flight will already have been added to the clock.

If you have to make an emergency landing on a road in Allied territory, you can be back at your base with a time-penalty of no more than a few hours, but it may take a day or more to return your aircraft to the flight line. If reserve aircraft are available you'll notice no change in your strength, but if your reserves are depleted then your strength will be reduced temporarily. The same effect may be observed when your aircraft returns damaged and needs repair, or when heavy losses in the air or on the ground outstrip the rate of replacement.

Relocating to another airfield

As the campaign progresses, your commander may decide to base you at a different airfield. This decision could be prompted by a variety of factors. For example, your current base might be threatened by an enemy advance or badly damaged by air attack, your priority targets might be clustered on the other side of the map, or enemy action might have disrupted the supply system in the base area.

When the order comes to do this, the Air Tasking Message will conclude with a line like 'Relocating to Allied 3', and the skeleton flightplan will show a landing at the new base. Landing anywhere else will incur the ferry-flight delay.

SECTION 2b - LEVEL TWO CAMPAIGNS

At this level, you are responsible for creating flightplans for your whole formation of Tornados and setting up coordinated attacks. This section assumes that you have mastered the process of mission planning for a single aircraft.

A Task at this level will normally prescribe an attack on a large enemy installation - an airfield, for example - assign targets to each aircraft and specify a Time-on-Target. It will be your responsibility to set up the individual attacks and their precise timing. Here is a list of basic principles for achieving a successful coordinated attack:

1: Concentration in Time. No-one reacts instantly; it always takes time to grasp the situation and work out a response. This is true of AAA and SAM crews and also of their equipment - it takes time to slew and elevate a gun barrel or a launcher, and time to defeat your ECM. If your entire attack is compressed into the space of a few seconds with no advance warning you may be gone almost before the enemy has started shooting. If your attack consists of four aircraft making separate passes in sequence, the first aircraft through may escape undamaged but the rest will almost certainly be shot to pieces. Even if you don't achieve complete surprise, you can still hope to saturate the defences. The

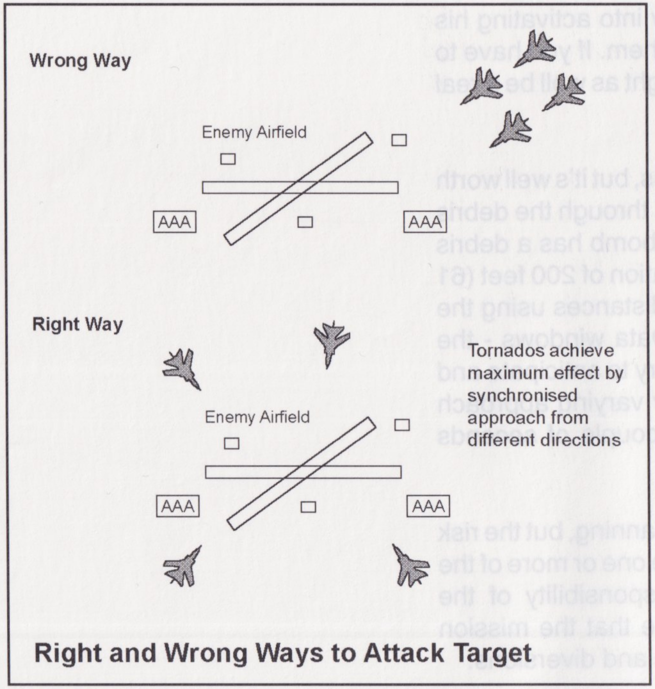


diagram 5.14

idea here is that you have many guns shooting at many different aircraft rather than many guns shooting at one aircraft at a time.

2: Dispersion in space. So you set up your attack with four Tornados making a single fast sweep over the target in tight formation. You're in and out in thirty seconds or less, but everybody gets hit. What went wrong? This should be obvious - all the defences were shooting in the same general direction at the same time. The enemy can concentrate all his firepower on the small volume of space which contains all of your aircraft, and stands an excellent chance of hitting something, even if it wasn't what he was aiming at. If you send the aircraft in from many different directions at the same time, you divide the enemy's fire and reduce his chances of scoring a hit.

3: Go for the defences first. And do it from as far away as possible. ALARM's Indirect mode was designed for situations like this, but when the weapon is 'loitering' there may be quite a delay between the time when the defence radars turn on, and the time the missile hits them. You may need to provoke the defenders into turning on their radars BEFORE the strike arrives - but if you're going to alert them it would not be a good idea to concentrate their attention in the direction from which the main strike is approaching.

Another 'stand-off' tactic would be to pop up far enough to see the defences on your ground radar, designate them as targets-of-opportunity, and then perform a loft attack on them. The main difficulty here is in identifying defences on the radar display, which can only be done on the basis of their positions around the field. It is standard practice to set up AAA close to each end of a runway to give the sites a minimum-deflection shot against a runway-cratering attack, but SAM launchers may be harder to spot. Obviously a single attack of this type can only hope to take out a single site, but this might be a good way

of achieving the object stated above - tricking the enemy into activating his search and weapon radars so that ALARM can home on them. If you have to provide a visible threat in order to attract his attention, it might as well be a real one.

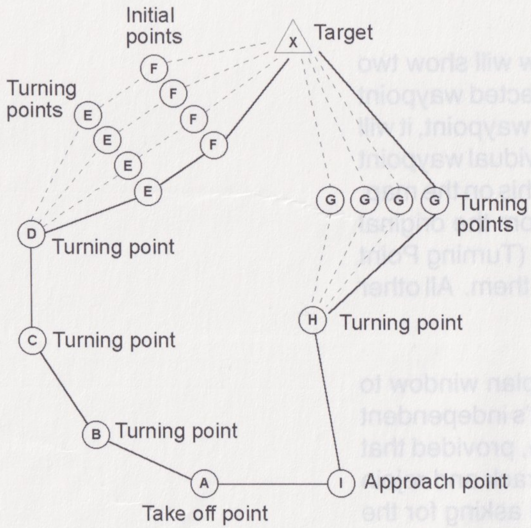
4: Try to avoid blowing each other up. This should be obvious, but it's well worth repeating. Don't set up the attacks so that one aircraft flies through the debris hemisphere of another's bombs. Assume that a 1000 lb. bomb has a debris hemisphere of 1000-feet (305 m) radius, and that a separation of 200 feet (61 m) is adequate for all other weapons. You can estimate distances using the coordinate displays on the Target Waypoint and Point Data windows - the coordinate values are in tens of metres. While you're at it, try to anticipate and avoid potential collisions. You can achieve separation by varying approach direction, altitude or Time-On-Target (but only within a couple of seconds either way - see next point).

5: Be on time. If you're not, not only will you waste all your planning, but the risk will be increased for every aircraft involved, as you sacrifice one or more of the principles given above. Arriving on schedule is the responsibility of the individual aircrew, but it's up to you as planner to ensure that the mission timetable has enough slack in it to survive minor mishaps and diversions.

As with all 'wish lists' of this sort, it may be difficult or impossible to achieve all of these objectives at once. You'll have to decide for yourself how to strike the balance between them. The enemy's disposition and level of awareness will determine just how much you can get away with.

Flightplans for Formations

At Campaign Level Two, when you enter the Mission Planner you will see a Task outline, just as at Level One. For most of any Flightplan, all your aircraft will be flying the same route in a widely spaced formation, and their individual waypoints, legs and times are automatically generated at an offset from the formation leader. Approaching the Target, the formation will split as aircraft



Formation Flightplan for Four Aircraft

diagram 5.15

diverge to their individual Initial Points to start their separate Attack Runs on different targets. Each aircraft will then follow its own Egress Run until the formation reforms at a set rendezvous, with timings and speeds set up so that all aircraft arrive simultaneously at their correct positions. They then follow a common route (with automatically staggered Waypoints and Times) back to the airfield for landing.

In a Formation Flightplan there will be one button in the Aircraft Strip of the Flightplan Window for each aircraft in the formation. A is the Formation Leader - you. Clicking on an aircraft letter selects that aircraft's flightplan for viewing and editing.

All aircraft in a formation will have exactly the same number of waypoints and legs in their flightplans. Some will be formation waypoints, where the Formation Leader's waypoint automatically determines the position of the corresponding waypoint for every other aircraft currently in the formation. Others are independent waypoints, where each aircraft's position and all other waypoint attributes can be set individually, within certain limits .

Limitations on Waypoint Editing

Insertion or deletion of waypoints can only be done when the waypoints or legs affected are common to all the aircraft in the formation. Buttons for functions not allowed for the current wayoint will be disabled. This is why the skeleton flightplan generated for a multi-aircraft mission includes a Turning Point between Take-off and Target, and another between Target and Approach Point. If these waypoints were not included you'd find it much less convenient to insert new waypoints in the flightplan - don't delete them.

Split and Formate

The rightmost button in the Tool Strip of the Flightplan Window will show two alternative legends according to the nature of the currently selected waypoint - 'Split' or 'Formate'. When the selected waypoint is a formation waypoint, it will show 'Split', and clicking on the button will make this into an individual waypoint for all aircraft in the formation. You'll be able to see the effect of this on the map, since the individual waypoints will automatically spread out from the original position. Each independent waypoint will be of the same Type (Turning Point or Target) as the formation waypoint which was split to produce them. All other waypoint attributes except position will also be inherited.

You can now use the buttons in the Aircraft Strip of the Flightplan window to select the flightplan of any aircraft in the formation. Each aircraft's independent waypoints may be dragged about or edited in any way you like, provided that it's physically possible for each aircraft to fly its independent track and rejoin the formation on time at the next formation waypoint. If you're asking for the improbable or the impossible, you'll see a WARNING or ERROR in the Problems window. This obviously adds another kink to the problem of 'Bound' Times and Speeds, but once again the problem is inherent in the situation, and you'll have to learn to handle it by experiment.

When the selected waypoint is an independent waypoint, the button will show 'Formate'. Let's say that your currently selected waypoint is D, an independent waypoint, and you've selected aircraft B's flightplan. Clicking on 'Formate' will turn D into a formation waypoint at the same position. The formation waypoint attributes will be inherited from the original independent waypoint.

This system of setting all waypoint attributes from the one selected to split or formate upon is intended to save you time and trouble. For example: at Command level you'll be creating flightplans for multiple aircraft attacks from scratch, and the inheritance system means that you can create one target waypoint for the formation, then split it into as many independent target waypoints as you have aircraft. If we didn't support this, you'd need to change the type of every independent waypoint by hand!

As ever, every silver lining has a cloud. The skeleton flightplan automatically generated from the Tasking Message will give every aircraft an identical Time-On-Target. If the targets are closely spaced, this would result in your aircraft blowing one another up. As we suggested above, you will need to adjust direction, altitude and time of attack to ensure that this doesn't happen.

SECTION 3 - COMMAND LEVEL

At this level, you have complete command authority. At Campaign level you had the job of turning a Task into a flightplan; at Command level you create the Task as well. You will need to exercise all the skills you have already learnt in mission planning and flying, but in addition you will need to make the all-important decisions about what targets to strike, and how to divide your resources. This section assumes that you are familiar with all the material covered in the first two sections of this chapter.

In order to select 'Command' on the Flight Options page, the pilot whose log is currently selected must be Command-qualified, holding the rank of Wing Commander or Group Captain. When you start 'Tornado', Group Captain deFault's log is selected and he qualifies. If you select 'Command' using the deFault log, and then call up the Pilot Log screen in order to select another log, only the logs of Command-qualified pilots will be available.

As with the 'Campaign' option, the Mission Selection Screen for Command level presents a selection of starting scenarios, and allows you to select any one of the three War Zones. In addition, you can save one Command game per War Zone to reload and continue later.

The Mission Planner in Command Mode

When you commit to a Command scenario, you will see that the Mission Planning Screen looks exactly as before except that the Map Screen Button which used to read 'Briefing' or 'Task' is now titled 'Command'. Also, if you click

on the Flightplan button straight away, the Flightplan window will not appear. This is because you haven't yet created any Tasks, which can only be done by calling up the Command Window. You probably won't be surprised to learn that you call up the Command Window by clicking on the Command button.

The Command Window

This window allows you to review intelligence data to help in selecting your objectives, and then issue the orders to accomplish them. It contains a strip of buttons at the top, and its lower portion (the Priority Target Finder) closely resembles the Target Finder called up by the Targets button. The buttons are labelled 'Situation', 'Air Power', 'Relocate' and 'Tasking', and their functions are described below:

Situation
This calls up the Situation Report window, which provides a summary of the overall military situation. Use this to make decisions about the general nature of your operations. Are Allied ground forces so hard-pressed that all your effort must be devoted to supporting them? Is your base airfield threatened by advancing enemy forces? How much difference did you make with your last strike on the enemy supply line? How effective are enemy air operations? What's the state of your own supply system, and what can you do about it?

Many of the more specific questions will need to be answered with the aid of other Command window facilities, but the Situation Report is intended to give you the big picture, providing a context in which to evaluate detailed intelligence. Use it - or you run the risk of winning your battles but losing the war.

Air Power
This button calls up the Air Power window, which summarises the location, nature and strength of air force units on both sides. Data regarding enemy forces is not guaranteed to be complete or 100% reliable. Use this window to gauge the progress of the air war and guide your selection of targets for Counter Air operations.

Relocate

Click on this button to call up the Relocation window, which shows buttons corresponding to all serviceable Allied airfields. If you need to shift the force of Tornados under your command from their current base to another, you can do it from here. There are many possible reasons for doing this: your base may be endangered by advancing enemy ground forces, or under-supplied, or too far from the action, or too vulnerable to enemy air strikes.

Your current base airfield will be highlighted - to shift your Tornados to another airfield, just click on the appropriate button. Be aware of the danger of concentrating too many Allied air resources at one base; if the enemy mounts a powerful strike against it, he may destroy or ground a critical proportion of your available forces in one operation. If the enemy's counter-air capability is destroyed or degraded, however, the risk may be acceptable.
When you use this facility to shift your base, all flightplans for the tasks you generate in this round should be set up for landing at the new base. Tornados landing elsewhere (including the old base) will incur the normal time-penalty for ferry flights.

Tasking

The Tasking window called up by this button allows you to allocate Tasks to formations of Tornados, or single aircraft. Once you have created a Task, you can create the flightplan(s) for that Task. The window shows the number of Tornados available for operations, both IDS and ADV. When you first call up this window in each round, one line will be displayed showing a Mission number followed by a button showing the type of Tornado assigned, with a Cycle button beside it. This button will initially show 'None', but by clicking on the Cycle button it may be changed to read 'IDS' or 'ADV', depending upon availability of the type.

When the type is changed to something other than 'None', two further buttons appear to the right, each with a Cycle button beside it. The first shows the number of aircraft assigned to the formation, defaulting to 1. The associated Cycle button can be used to change the number of aircraft between 1 and the maximum available, and as this figure is changed the availability figure will

fluctuate accordingly. You can't change the figure to 0, but the same effect can be achieved by selecting a Type of 'None'. The rightmost button can be used to display a description of the mission type as a reminder of your intentions. Click on the Cycle button to view the descriptions available, and use the most appropriate.

When you create a Task by assigning aircraft to it, a mission number for a further Task will appear on the line below, up to a maximum of four Tasks or until all available aircraft are assigned. You may only modify aircraft assignments for the latest Task in the list - if you change your mind and want to modify tasks earlier in the list, you must delete all later tasks by setting their aircraft types to 'Nne', in order from the last backwards. You should also bear in mind that you will ALWAYS fly aircraft A in the first Task in the list. Once a Task has been created by assigning aircraft to it, its flightplan may also be created in the normal way by calling up the Flightplan window. You can select which Task's flightplan to edit by clicking on the appropriate mission number in the Tasking window.

Priority Target Finder

This system gives you easy access to processed intelligence data, showing you which facilities are most important to the enemy's war effort. These facilities should therefore be the most desirable targets. Which category of target you set out to strike should be determined by the broader view you gain from the Situation Report and Air Power windows. The quantity and quality of intelligence available will govern the quantity and quality of the evaluations provided by the Priority Target Finder. It is within your power to improve the level of intelligence available to the Allies - see below under Comms. Parallel calculations are made from the enemy viewpoint, to display the nearest Allied equivalent to each Priority Target, if one exists. If it's worth doing, do it to them before they do it to you.

Like the Target Finder, the Priority Target Finder shows two columns; the left being used to select a broad class of targets, and the right to display a complete list of all the individual items in this class. The items on the right are each

marked with one of three symbols, a tick, a cross or a question mark. A tick indicates that intelligence can offer you targets of this type, whereas a cross tells you that no information is available - better intelligence is needed. A question mark indicates that intelligence is still being evaluated - targets aren't available yet, but they will be sometime soon. When such items are ready, the symbol will change from a question mark to a tick. Obviously, you can only select ticked items for display on the map.

The Priority Flag markers work just like the Category Flags, they are automatically enabled when this window is open, but when it's closed you can use the Key window to contrl whether or not they are displayed. Here's a list of all the possible classes and items, which are significantly different from those in the Target Finder.

Class: Command

This class selects enemy headquarters, where known, and flags the most important. Destroying an HQ may have serious effects on the coordination of enemy forces and the efficiency of the enemy supply system.

Command: Rear HQ

These are permanent hardened facilities normally well behind the line of battle and very well defended. The highest level of command is found here, and a successful strike may seriously disorganise the organisation and movement of enemy reserves and supplies. The effect on enemy forces directly engaged at the front is real, but not immediate or direct - it may take some time before the results are apparent.

Command: Field HQ

These are the headquarters of force commanders close to the front line. They are normally very soft targets relying on camouflage and mobility to avoid detection, but there will usually be local AA defences. Destroying a Field HQ will have an immediate effect on forces engaged in battle, but this effect may not last for long. There may be a short-term gain in intelligence as enemy message traffic increases in the attempt to compensate for the damage to the command structure.

Class: Comms

Communications targets are important in themselves, and vital for the potential effect on intelligence. Most of the secure communications on both sides are routed through a limited number of sites connected by land-line or lines of sight. Every time one of these centres is put out of action, message congestion increases on the remaining parts of the secure net and installations served by the destroyed facility must resort to less secure channels. This insecure message traffic at the very least reveals locations, and may yield high-grade intelligence. This can vastly improve the efficiency of your operations.

Comms: Main Node

These are permanent facilities, easily recognisable by the microwave relay tower on the site. They will normally be well defended. Each is in line-of-sight with at least one other, forming a network. Priority will normally be give to Main Node targets which serve the battlefield area, or which represent points where the comm. net may be cut, in order to achieve the maximum increase in insecure message traffic. Enemy organisation and supply may also be affected as the network is degraded.

Comms: Field Relay

These are temporary camouflaged installations providing secure communications between the battlefield rear area and the main comm. net. Destruction of a Field Relay should improve the yield of local intelligence, and disrupt local command and supply to some extent.

Class: Logistics

This class of targets covers the enemy supply system - perhaps the most important class of all. There's a standard quote which says that 'amateurs study tactics, professionals study logistics', and it becomes more and more accurate as time goes on. Advances in military technology usually seem to mean that weapons get expended faster and more vehicles use more fuel. The days when an army could largely support itself by foraging in the local countryside are at least a century gone; modern forces consume almost unbelievable tonnages of stores - and always more than they planned for.

As a result of this, all roads and railways leading towards the battlefield will be vital channels of supply - if you can cut these channels the enemy's fighting power will be very seriously reduced. Other important targets in this category are the stockpiles at each end of the supply routes.

Logistics: POL Installations

POL is the standard military abbreviation for Petrol, Oil, Lubricants. If stocks of these are seriously depleted, all vehicles from trucks through tanks to aircraft will be seriously affected, though airfields normally have large stocks on site in well-protected underground tankage. POL installations are generally permanent and hard to hide, hence they will almost always be well defended.

Logistics: Main Depots

These are main centres of supply - major stockpiles holding huge quantities of everything needed to supply armed forces. Take these out and the supply pipeline will empty as stores are consumed but not replaced. You will not totally prevent resupply, but it will be thin and intermittent. These are large conspicuous installations with defences, usually too large to destroy in a single attack.

Logistics: Forward Dumps

These are small, dispersed, camouflaged stockpiles which supply the needs of local forces and are replenished in turn from the major stockpiles. Destroying one of these should have a powerful local effect.

Logistics: Choke Points

Choke points are places where transport routes can be cut with maximum effect and efficiency - in Tornado, all choke points are bridges. This can be a very effective way of crippling the enemy supply system. Alternative routes will often exist, but they will usually be longer - all supply convoys will normally be sent by the shortest available route from A to B.

On a typical Tornado map there are a great many bridges, so this priority facility tries to analyse enemy traffic patterns and select as targets those bridges which are most heavily used. The value of these points is also obvious to the enemy, so these targets may well be defended.

Class: Politics

This is a miscellaneous category for targets which are not strictly military. Some may adversely affect enemy morale, some may help preserve allied morale. One (Decapitation) offers your best chance of bringing a war to a quick conclusion.

Politics: Power Station

Depriving the enemy population of power may have a significant effect on morale - provided that it is already depressed. It's not a war-winning move if enemy forces are doing well.

Politics: SCUD Launchers

The classical political distraction target, familiar to all Gulf War fans. The missiles are so inaccurate that they have very limited military value when fitted with conventional warheads, but unfortunately their effect on civilian morale can far outweigh the little damage they're likely to do - in fact a city is about the smallest feasible SCUD target. The other problem is that they're mobile and hard to find. If you decide to go looking for them, don't expect to find them exactly where intelligence said they were. SCUD-hunting is necessarily a solo exercise that you'll have to take on yourself, using the ground radar and the cameras and probably flying at night.

Politics: Decapitation

A Decapitation (beheading) strike is designed to take out your enemy's political leadership, on the assumption that their successors will either be more willing to talk, or will paralyse the military command structure by fighting among themselves for power. The main prerequisite for a Decapitation strike is really excellent intelligence - you won't be offered this type of target until it's available.

Politics: NBC Capability

NBC is for Nuclear/Biological/Chemical weapons. If this category of target is offered, they represent research and manufacturing sites rather than stockpiles. These weapons will never be used in the war you're fighting, but the destruction of the facilities might be an important morale booster for your side.

Class: Battlefield

These targets represent places where you might directly influence the land battle. Two of these types of target represent the (approximate) locations of enemy AFVs (Armoured Fighting Vehicles). Don't go for them unless the overall situation is desperate. They'll be very heavily defended, you'll need to spend time in an extremely dangerous environment looking for them, and target recognition is difficult. When you do find a target, you're unlikely to be able to take out more than one small group of vehicles at a time. The third type of target, the Repair Centre, is a much more sensible place to strike.

Battlefield: Direct Support

These are Close Air Support targets - enemy forces in contact with allied forces. Target recognition is critical to avoid shooting up your own troops - and very, very difficult.

Battlefield: Reserves

As the name suggests, these are the locations of enemy armoured units in reserve. The problem of target recognition is less important here (provided that you know where the front line is), and the available targets may be more concentrated. Still a risky sort of target.

Battlefield: Repair Centre

AFVs of all sorts are complex and surprisingly delicate machines. If they're doing anything more strenuous than standing still, they break down regularly and require frequent specialised maintenance. When you add battle damage repair to this maintenance load, it becomes an enormous task, and the efficiency of the repair system has a dramatic effect on the front-line strength. Repair and maintenance take place at all levels from units in the field up to major workshops with heavy equipment and large stocks of spares. If you can knock out or seriously damage these major repair centres it can have a devastating effect on enemy ground forces, because repair of anything worse than minor breakdowns and battle damage will slow down severely or stop altogether. Repair centres are found at large military bases, and you can expect them to be well defended. Priority flagging of a repair centre shows that it is directly supporting the enemy battlefield forces.

Class: Counter Air

These are all types of target which are important to the air war in different ways. A heavy effort against these targets should go a long way towards winning air superiority (or even supremacy). If you can achieve this desirable condition, where the enemy is unwilling or unable to defend his airspace, then you can methodically destroy his resources at minimum risk to your aircraft.

Counter Air: Airfields

If Allied intelligence is good enough, you can already see from the Air Power Window which aircraft types the enemy is operating from which airfields, and that information should be a useful guide in choosing airfield targets. The targets flagged in this category are those where some combination of factors makes it especially tempting to strike them.

Counter Air: EWR

It's easy enough to find EWR sites using the ordinary Target Finder, but this facility will highlight the EWR stations which are most valuable to the enemy, taking the distribution of targets into account.

Counter Air: Defences

This is intended to highlight the densest defences masking the most valuable targets. Remember the principle that 'if it's worth defending, it should be worth attacking'. Concentrated defences are also good ALARM targets, and if the enemy keeps bringing in defensive units from elsewhere to replace those lost, you can strip away protection from a wide area of enemy territory.

Counter Air: C^3

This is 'C-cubed' rather than 'C-three', and stands for Communications, Command and Control. If intelligence can identify a coordinating centre for enemy air activity, this is how it will be shown. This will inevitably be a hardened, camouflaged target - a bunker, by any other name. Taking out every such target which appears is quite an effective way of achieving air superiority, but you need good intelligence to do it.

You have Control...

You've got the aircraft and the planning system system to fight this war - do you have the experience and imagination needed to win it? There's only one way to find out. The contrasting geography of the three War Zones presents a variety of dangers and opportunities, and the different scenarios available mean that there should be enough challenges to keep an enthusiast busy for some time. If simple victory doesn't satisfy, you can experiment with different ways to win. This is the way to get maximum use and enjoyment out of this software.

As far as we can, we've tried to model Tornado on the real world in order to increase your scope for imaginative tactics and strategy. Though we've broken a lot of new ground and the hardware is getting faster, simulating an entire war in the background with high fidelity is still far beyond the capability of mass-market computers. We can't claim that real-world tactics will work here, or that the reverse is true, but we can state categorically that there's no single way to win. There are also, of course, many different ways to lose.

DEBRIEF

CHAPTER 6

DEBRIEF

Ending or Aborting your Flight

At the end of your flight, you must use the key combination Ctrl Q to leave the cockpit. For any flight outside the Simulator or the 2-player option, you must land and bring the aircraft to a halt before you do this, or you will be considered to have aborted the flight, and you will not be allowed to log it.

No matter how you started a flight, at the end of every one you'll see the Debrief Screen. This will summarise your performance, and the exact data will differ depending upon what you've been doing. For every type of flight except when using the Quickstart option or Group Captain deFault's log, or if you aborted, you'll be presented with the choice of whether or not to log the flight and add the flying time and achievements to the log record. If you died, went missing or were captured in the course of the mission, logging the flight (by clicking on the 'OK' button) will mean that the current log will lose its Active status, and you won't be able to use it again.

If you decide not to log the flight, click on the 'Cancel' button and the mission and its outcome will completely disappear from the record. Everything will be exactly as it was just before you took off, so you can try it again or go back to the drawing board, whichever seems better.

You can't be killed or captured in the Simulator, in a 2-Player game, or under the Quickstart option. All other types of flying involve some degree of risk, whether from flying accidents or enemy action.

Regardless of the outcome and the type of flight, your flying time will always be shown. Other information presented will depend heavily on the type of flight - the following list is not exhaustive, but most items should explain themselves.

Landings

You will be notified if you touched down heavily, and the aircraft may be damaged. If you landed hard enough to collapse the gear, the aircraft will certainly be damaged and may be destroyed.

Damage

If your aircraft was damaged in flight or by a hard touchdown, you will be notified.

Repair

Within a Campaign or Command scenario, an aircraft will be unavailable for the time taken to repair it.

Diversion

Within a Campaign or Command scenario, if you land away from your current base you will effectively lose the time taken to ferry your aircraft back.

Targets

If your mission included planned targets, you will be informed whether or not you achieved their destruction.

Victories

If you shot down aircraft or destroyed other vehicles in the course of your flight, you will be told how many.

Losses

Losses of aircraft and vehicles during your flight will be tabulated for both sides.

Bombing Accuracy

This only applies to the Bombing Range mission available in Training, where you must drop a single weapon on the practice target. Four types of message are possible:

Score: '50 at 1', or '180 at 6' are examples of typical scores. The first figure is your miss distance in feet, the second gives the miss direction in clock-face

terms. For example; '180 at 6' would mean that your bomb fell short by 180 feet, '30 at 3' would mean that your bomb fell 30 feet to the right of the target. Note that you must make your attack run flying directly North (a heading of 360°), or the clock figures won't be meaningful. Miss distances of greater than 500 feet will not be scored.

'Delta Hotel'	A dead hit, a perfect score.
'No Spot'	The bomb wasn't seen. Presumably you didn't drop it.
'Splash'	No score - a miss distance of over 500 feet.

Leaving the Debrief screen

This is done by clicking on one of the two buttons in the lower part of the screen. The text on these buttons will change according to the situation, but will always start with either 'OK', or 'Cancel'. When you were flying under a log identity you created yourself, provided that you did not abort the flight one button will show 'OK - Log Flight', and the other will show 'Cancel - Do Not Log'. Be sure that you understand the consequences before you choose to log the flight.

When you leave the Debrief Screen, you may find yourself on any one of a wide variety of screens, depending on the nature and the outcome of your flight.

Quickstart flights

You will always be returned to the Main Screen.

Simulator flights

If this was a 'start airborne' exercise, you will always return to the Mission Selection Screen. If the exercise started on the runway (which means that you reached the cockpit by way of the Mission Planner), the 'OK' exit will take you back to the Mission Selection Screen, while the 'Cancel' exit will return you to the Mission Planner, giving you the opportunity to review the flightplan and try again, or leave using the Exit button.

Training

The 'Cancel' exit will always return you to the Mission Planner. If you click on 'OK', what happens will depend on the outcome of the flight. If the pilot is still Active, you'll find yourself on the Mission Selection Screen. If your pilot lost Active status through death or dismissal, you'll be returned to the Log screen to choose another pilot, and when you leave there you'll be on the Mission Selection Screen.

Mission

As for Training.

Campaign

'Cancel' will always return you to the Mission Planner and set the clock back, regardless of the outcome of the mission. If you click on 'OK' with your pilot still active and the Campaign unfinished, the military situation will be updated to take account of everything which happened during your flight, and you will be returned to the Mission Planner to fight the next round. If your pilot lost Active status, the campaign will end and you'll be returned to the Log screen to choose another pilot.

If you want to save the situation to continue later, you can do this by selecting Exit from the Mission Planner. This will return you to the Mission Selection Screen, where you will automatically be presented with the option of saving the current state. This is your only chance to save - do it now or lose the opportunity.

Command

As for Campaign.

2-Player

You will always return to the 2-Player screen, where you can choose whether to fly again or disconnect.

Quitting Tornado

The most convenient way to do this is by using the 'System' command available from the Options button. Alternatively, you can use the Exit button to step back through successive screens to the Main Screen. Selecting Exit from there will give you the choice of quitting the program.

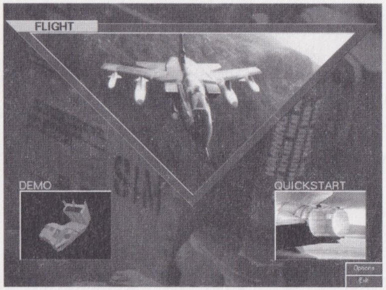
ELEMENTARY FLYING TRAINING

CHAPTER 7

ELEMENTARY FLYING TRAINING

INTRODUCTION

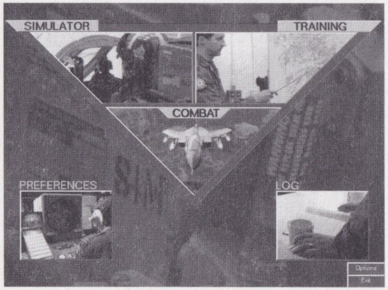
If you're at all uncertain about how to fly Tornado, this is the place to start. In this chapter we begin from absolute basics, and aim to reach the point where you can take off, fly simple manoeuvres safely, and land with assistance from the autopilot. Simply flying an aircraft a short distance from A to B is not at all difficult, as any light-aircraft pilot will tell you - in many ways it's less demanding than driving the same distance. Over longer distances navigation becomes the biggest problem, but the Tornado automates almost all of this. Taking off is a little more complex, but still quite straightforward. Landing is admittedly the most difficult manoeuvre in ordinary flying, but the Tornado autopilot can give you a lot of help. Mainly it takes practice to get it right - and you can practise in the simulator, where you can learn from your mistakes rather than die from them.



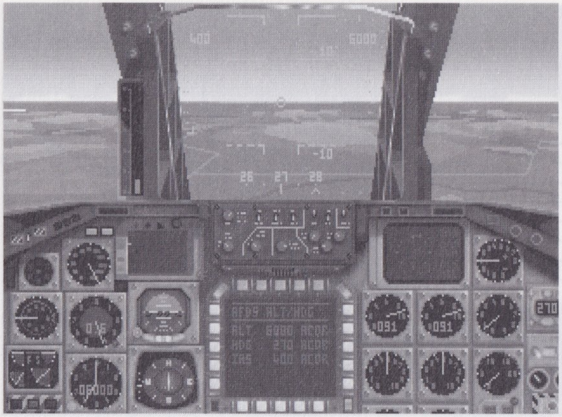
Main Screen

STARTING THE SIMULATOR

If you haven't done so already, start the program according to the instructions on the separate Technical Supplement. Once the Main Screen is displayed, click on the large triangular 'Flight' icon, which will divide into three parts. Click on the part marked 'Simulator', and you will be presented with the Mission Selection Screen. Click on the first choice in the list, marked 'IDS - Free Flight - Airborne', and a window will appear, giving details and showing two buttons. Click on the one marked 'Confirm'. After a pause for loading, you'll find yourself in the air.



Simulator, Training or Combat

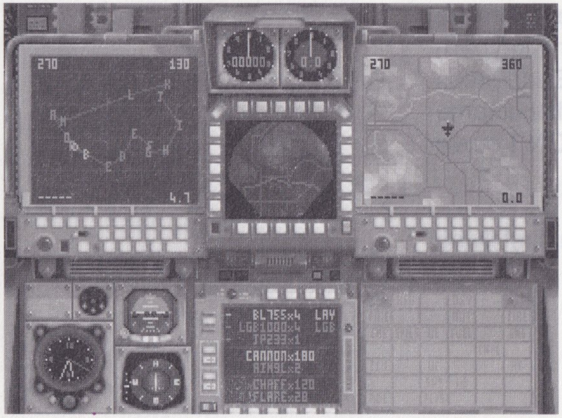


Pilot's Cockpit

Quick Cockpit Tour

The aircraft will fly itself straight and level quite happily, but just to be on the safe side, before you do anything else let's turn on the autopilot. Hit [F8], which turns on the AFDS (Autopilot and Flight Director System) in its Altitude and Heading Hold mode, which means that the aircraft will continue on in a straight line unless you tell it otherwise. A green light on the panel illuminates to tell you the AFDS has control. The yellow light beside it means that the Autothrottle is already engaged. Until you tell it otherwise, this system will throttle the engines up and down to try and keep you flying at the same speed. The aircraft will now look after itself while we show you around.

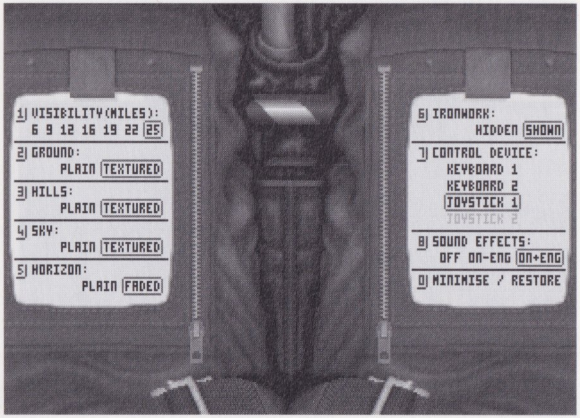
At the moment, you're seeing the view from the pilot's seat in the front cockpit, looking forwards. The lower part of the screen is occupied by the Front Panel, the outside world is visible above, through and past the HUD (Head-Up Display), the HUD support brackets and the canopy frames. Hit and hold the Look Left Key, and you're looking out of the left side of the cockpit. Release the key and you're looking forward again. The Look Right Key does exactly the same on the other side.



Navigator's Cockpit

Once you've returned to the forward view, hit the Back Cockpit key. You're now looking at the Navigator's Panel. Though the panel and the pilot's ejector seat block the view forward, you can use the Look Left and Right keys to see out - and you can also call up various camera views on the displays (more about this later). Hit the Front Cockpit key to return there, then hit the key again and you're looking up and forward. Hit it again to return to the standard front cockpit view.

Look Down - Choosing your Control Stick



Look Down View

Using the Look Down key in either cockpit gives you a view of your own legs - and more importantly, the kneepads which display a range of configuration options. Most of these are intended to allow you to set up the detail level of the outside visual to suit your preferences and the speed of your computer, but the important item for the moment is option 7 on the right-hand pad. This lets you select which of the available devices you're going to use as your control stick - the basic steering control of the aircraft. The options available will differ from computer to computer, but wherever possible the program will find out what's available on your machine, displaying unavailable choices in grey text rather than black. Check with the Control Summary and the Technical Supplement for your machine to ensure that you understand what each of the options means, and what each requires in the way of extra hardware.

What you choose for your control stick will obviously depend upon what's available and your own preference, but if you have any form of analogue joystick plugged in, that's what we would recommend. As with all these kneepad options, you switch the settings by pressing the number key (from the horizontal row on top of the typewriter keypad - NOT the numeric keypad) corresponding to the number of the item - in this case, the 7 key. Each press advances the setting through the range available. These keys work the same way in all view modes. Now select the control device you want but DON'T move it.

Switch back to the Front Cockpit view, and you're ready to start your first flying lesson.

FLYING THE AUTOPILOT AND READING THE HUD.

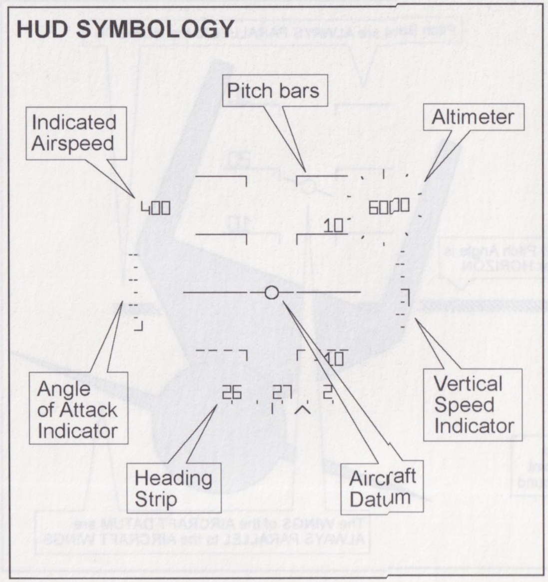
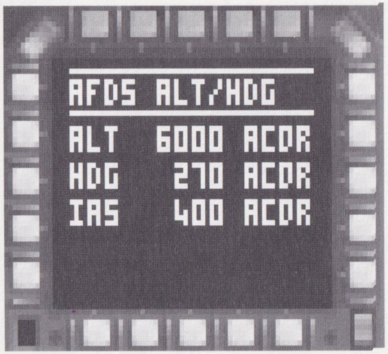


diagram 7.1

The first thing we asked you to do was to switch on the autopilot - now let's put you in control of it. If you look at the Multi-Function Display (MFD) screen in the centre of the instrument panel, you'll see that this is showing something like AFDS: ALT/HDG, followed by ALT 6000, HDG 270 and IAS 400.

These figures mean that the aircraft is trying to fly itself due West - a heading of 270°-at an altitude of 6000 feet above sea level (flat ground level in this case), and the Autothrottle has control of the engines and is trying to maintain an Indicated Air Speed of 400 knots. This is the Altitude/Heading Acquire and Hold mode of the AFDS. You tell it which way to fly and how high, and the aircraft will turn, climb or dive as necessary to fly in the right direction at the right height. These figures are not telling you the current state of the aircraft - they're telling you what orders the autopilot is trying to carry out. So how is it doing?

Look up at the Head Up Display (HUD) - *diagram 7.1*. At the top left you can see the Indicated Air Speed figure - it should show 400 (knots). At the top right is the Altitude figure - this should read 6000 (feet). Across the bottom of the HUD is a strip of figures above a scale marked in dots, and under both is a short vertical line, which should be directly below the figure 27. This is the Heading Strip, and it's telling you that the aircraft's compass heading is 270°-all the figures on the heading strip represent TENS of degrees. These are the actual readings telling you how fast, how high and in which direction the aircraft is currently flying. If you haven't changed anything, they should confirm that the AFDS is working well.



MFD in AFDS Mode

You should also take a look at the pairs of horizontal bars with turned-down inner ends which appear in the wide central section of the HUD (*diagram 7.2*). These are called the Pitch Bars (collectively the Pitch Ladder), and each is

marked with an angle in degrees, at 10° intervals. At the moment they're doing nothing because the aircraft is flying straight and level, but they give you vital information. Among other things they tell you which way is up, and whether the aircraft's nose is pointing at the ground or into the sky.

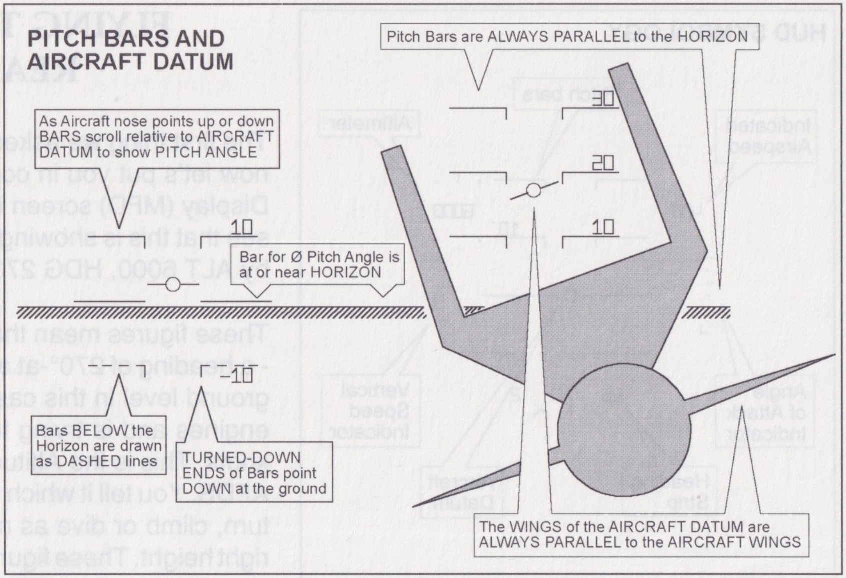


diagram 7.2

In this AFDS mode, your control stick does not fly the aircraft directly. Instead, you use it to alter the autopilot's instructions, and the autopilot then flies the aircraft to carry them out. Let's tell the aircraft to turn North. Move your control stick slightly right while watching the HDG (Heading) line on the Multi-Function Display (MFD) screen. You should see the heading figure start increasing towards 360° (at which point it snaps back to 0), and the aircraft will start manoeuvering to follow. Set the Heading figure to somewhere between 0 and 10 degrees, moving the stick right or left to nudge the number up and down - but don't worry about an exact value for the moment. If you're using an analogue joystick, the further you push the stick, the faster the numbers change. If not, then the longer you hold the stick over, or the key down, the faster the figures will change. If you hold the stick over too hard for too long and the AFDS heading figure goes past 090°, the aircraft will reverse its direction of turn because it's now quicker to turn left than right to get there! Just set the heading figure somewhere near 0° and let the AFDS sort it out for itself.

If you look back up at the HUD and the outside world, you'll see that the aircraft has rolled - banked - to an angle of about 45°, and the figures on the heading strip are sliding across as the heading changes. You can also see that the bars of the Pitch Ladder are at an angle on the HUD - they've stayed parallel with the horizon outside - and they always do. Notice that the turned-down inner ends of the ladder bars point down at the ground - this, too, is always true.

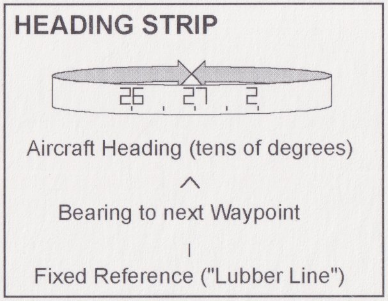


diagram 7.3

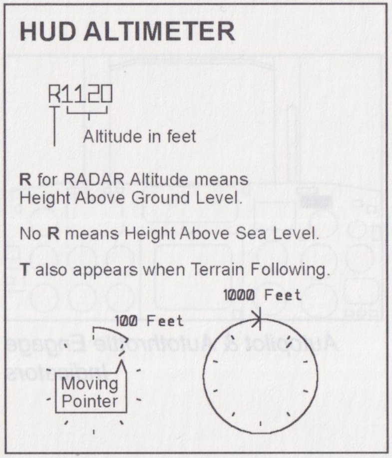


diagram 7.4

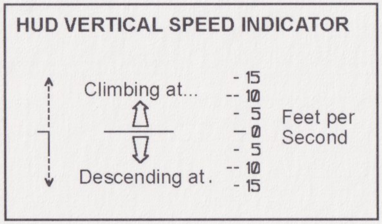


diagram 7.5

When the aircraft rolls level again, you should see that the reading on the Heading Strip is the same as the heading figure you set on the AFDS display (*diagram 7.3*). Now look at the ALT figure on the AFDS display. Pulling back on the stick will nudge this figure up, pushing forward will nudge it down. Set the figure to about 10000 feet. The aircraft will raise its nose and start climbing. On the HUD, you can see the Altitude figure changing, and the pointer on the 'clock' swinging clockwise around it (*diagram 7.4*).

Half-way up on the right-hand side of the HUD is the VSI - the Vertical Speed Indicator *(diagram 7.5)*. This is shown as a vertical bar which rises or falls from a centre position as the aircraft climbs or dives. Its scale is calibrated with dots at intervals of 5 feet per second. If the rate of climb or descent is bigger than the scale allows (and it often is), the bar extends to the end of the scale and stops. The precise rate of climb or descent is only normally relevant in the last stages of a landing, but the movements of the bar serve as a reminder of what the aircraft is doing.

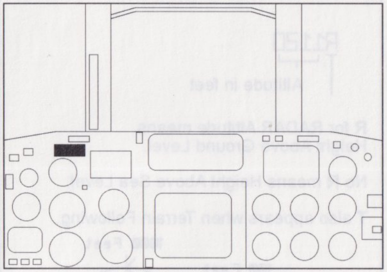
If you look at the Pitch Ladder, you can see that it's showing that the aircraft's nose (represented by the circle-and-two-lines symbol in the centre of the HUD) is pointing above the horizon. Now hit the F8 key again, which will reset the Altitude Hold target to your current height. We're about to reverse your last action and command the aircraft back down to its original height, but the aircraft will probably accelerate in the dive. With the wings swept forward for low-speed flight the aircraft will complain if asked to fly too fast. Hit the S key, pause for a second or two and then hit S again. This will ensure that the wings are fully swept back for high-speed flight. We'll look at why and how to manage wing-sweep later on.

Now push the stick forward to set the AFDS desired altitude back to 6000 feet - no lower. You can see that the aircraft puts its nose down, the VSI changes from showing a climb rate to a rate of descent, and the pointer on the Altimeter 'clock' is now swinging anticlockwise as the Altitude figure winds rapidly down. Looking at the Pitch Ladder, you can see that whereas all the bars above the horizon are solid, all the bars below the horizon are drawn as broken lines - another useful reminder that your nose is pointed at the ground.

If you've absorbed all this, you can now read most of the more important instruments, and you're ready to try flying for yourself, rather than just giving commands to the autopilot.

LEVEL TURNS AND AUTOTRIM

Remember the green and yellow lights near the top left of the panel? The green light is on when the autopilot has control, and the yellow light is on when the autothrottle is engaged.



Autopilot & Autothrottle Engage Indicators

When the aircraft is flying straight and level again, hit the [Esc] key. The green light should go out. Congratulations, you've just switched off the autopilot. If the aircraft was flying stably before you turned it off, nothing very much will change unless you move the control stick. Don't immediately grab the stick and clutch it with a vice-like grip - unlike a car, an aircraft can be left quite safely hands-off for long periods, provided that it starts in a stable condition - which is what the autopilot should have left you with.

During all of the following exercises feel free to use the [P] key to pause while you catch up, read ahead or try to work out what's going wrong. Hitting [P] again will restart the simulation. If you end up in a situation you can't handle, quit the simulator by holding down [Ctrl] and [Q] simultaneously, then restart.

Let's turn the aircraft to the left. Move the control stick a short way to the left, and then release it to spring back to the centre. The aircraft should bank to the left and then stop rolling. If it doesn't stop rolling, move the stick right and then release. Try to set up a bank angle of about 45° and stop it there, but you don't have to be exact.

If you now look at the HUD and the outside world, you should see that two things are happening:

- The aircraft is turning slowly to the left.
- The nose is dropping, and the aircraft is starting to dive and pick up speed.

The turn is what we wanted, but it's rather slow - and who said anything about diving? Pull back gently on the stick, and hold it slightly back. This should produce two results:

- The rate of turn increases.
- The nose should rise again. If it doesn't, hold the stick back further.

When the nose is roughly level with the horizon, relax the back pressure on the stick and try to keep the nose on the horizon. The outside world and the Pitch Bars on the HUD are the easiest visual references to use for this kind of manoeuvering.

If you're trying to fly with the keyboard you won't be able to use the stick this way. Because there is no way of reading how hard you're pulling back, the stick force just increases as you hold the key down longer. There's no way of reducing the stick force short of releasing the key altogether. All is not lost, however. Raise the aircraft's nose until it's level with the horizon or climbing slightly - the HUD VSI is a useful aid for this - and then quickly hit the Autotrim key (on most machines this will be the 5 key on the numeric keypad).

Autotrim is always available when the aircraft is upright, regardless of whether or not you're using the keypad as your control stick. When you engage Autotrim, you can move the control stick right or left to bank the aircraft to any angle short of about 80°, and the Autotrim system will pull back as hard as necessary to maintain the same rate of climb or descent. Autotrim is cancelled when you make any pitch input (that is, when you pull back or push forward on the control stick), or when the bank angle approaches 90° and it just isn't possible to keep the nose up any longer by simply pulling back on the stick.

Practise changing your bank angle and pulling back to speed up the turn and keep the aircraft level - but for the moment, don't try pulling back if your bank angle is much greater than 60°. Instead, roll the aircraft more upright before you try.

At any time when the aircraft is not banked beyond 60°, you may re-engage the AFDS in Altitude and Heading Hold mode by hitting key F8, at which point it will take the current heading and altitude as the values to hold. If you try to re-engage the autopilot while the aircraft is rolled further than this limit all hell will appear to break loose as red lights start flashing and sirens sounding. It's just the aircraft's way of making sure that you know that the autopilot is NOT flying the aircraft for you even though you tried to switch it on - you still have control. Cancel the Warning by hitting the * (numeric pad) or ' key and everything should return to normal.

Now that you know what to do to keep your turns level, let's look at why. You don't need and you quite probably don't want an aerodynamics degree course, but you do need some kind of simple mental picture of the situation. The simplest and best one available is the idea of the Lift Vector.

The Lift Vector

A Vector, for our purposes here, is just a force with a direction. Vectors are usually drawn on diagrams as lines with arrowheads. The direction of the line and the arrowhead shows the direction of the force. The length of the line represents the strength of the force. Look at *diagram 7.6*. Here is an aircraft stopped dead in mid-air. The only force acting on it is the force of gravity, so we draw a vector straight down towards the ground - that's the way the force will act. Let's say that the length of this line represents the acceleration due to gravity, times the weight of the aircraft - call it the Gravity Vector.

In this situation, the aircraft will obviously fall straight down. There's only one force acting on the aircraft, and it's acting straight down. Now imagine the aircraft flying straight and level. The force of gravity is still acting on the aircraft, but it's not falling. There's another force acting in exactly the opposite direction to the force of gravity, with an exactly equal strength. This is the lift force generated by air flowing over the wings - the Lift Vector *(see diagram 7.7)*.

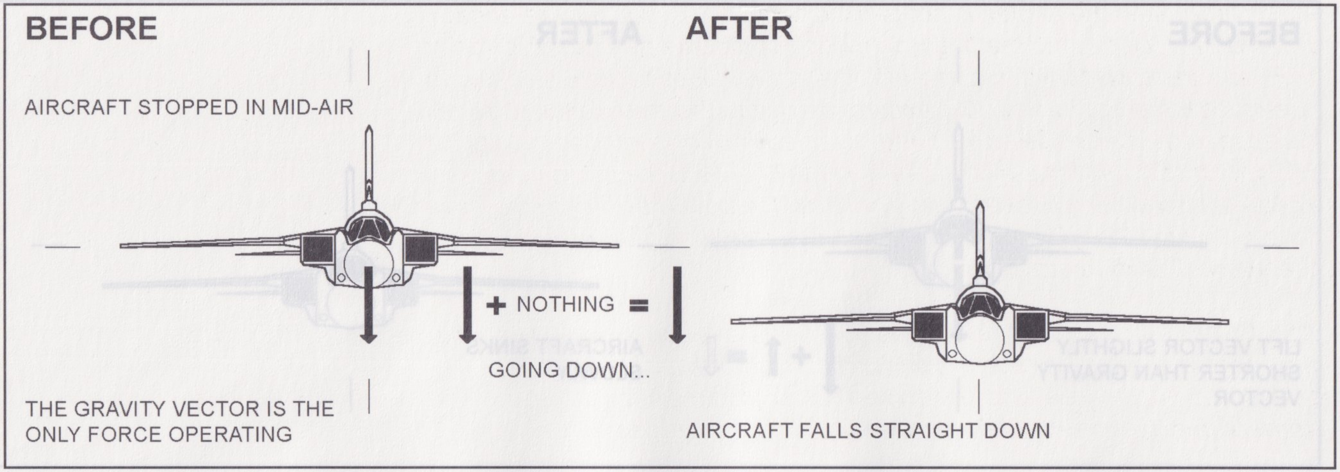


diagram 7.6

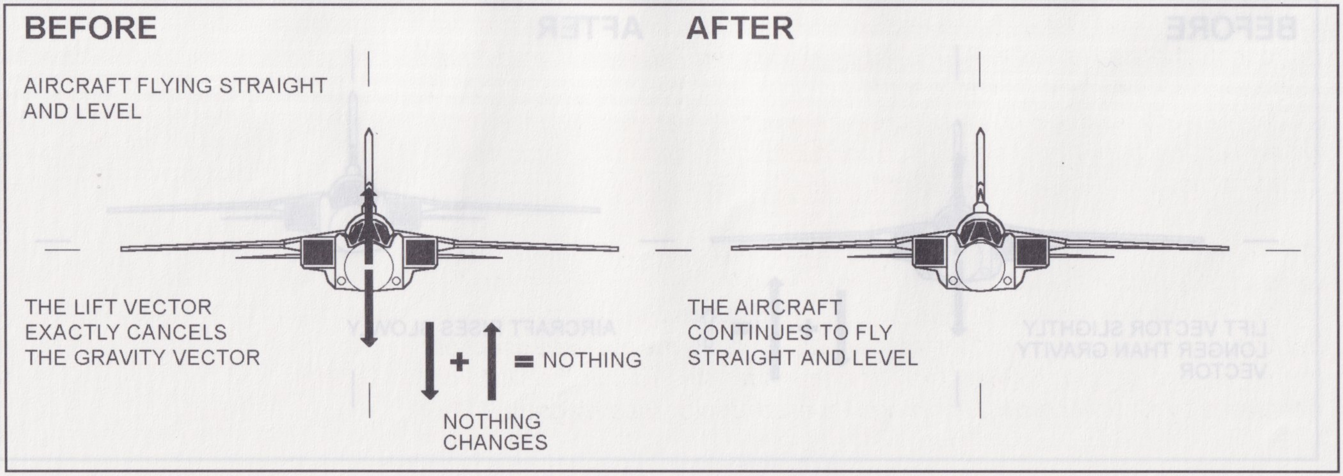


diagram 7.7

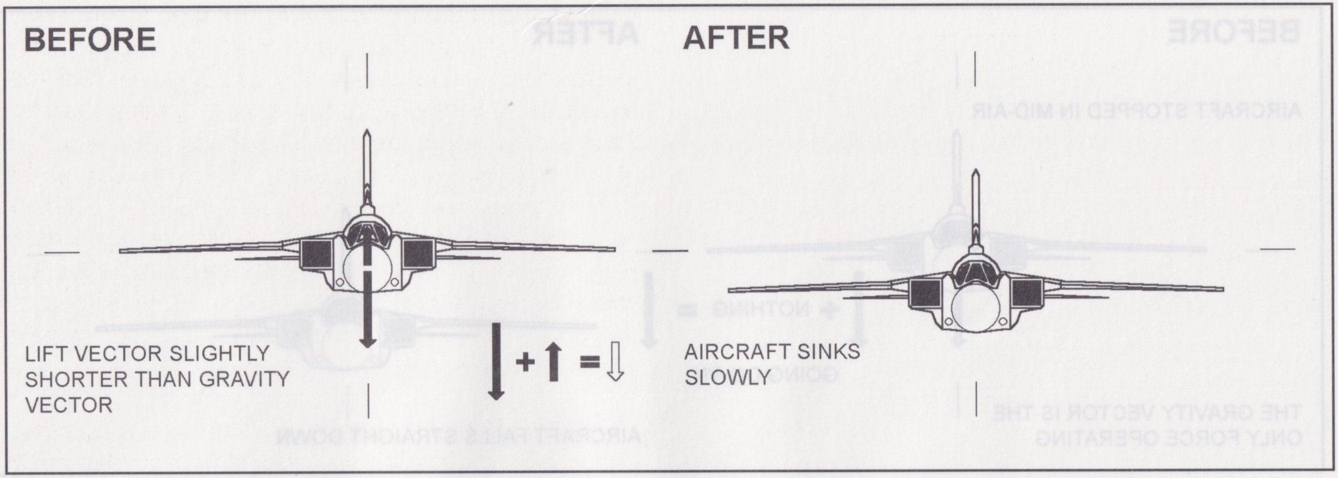


diagram 7.8

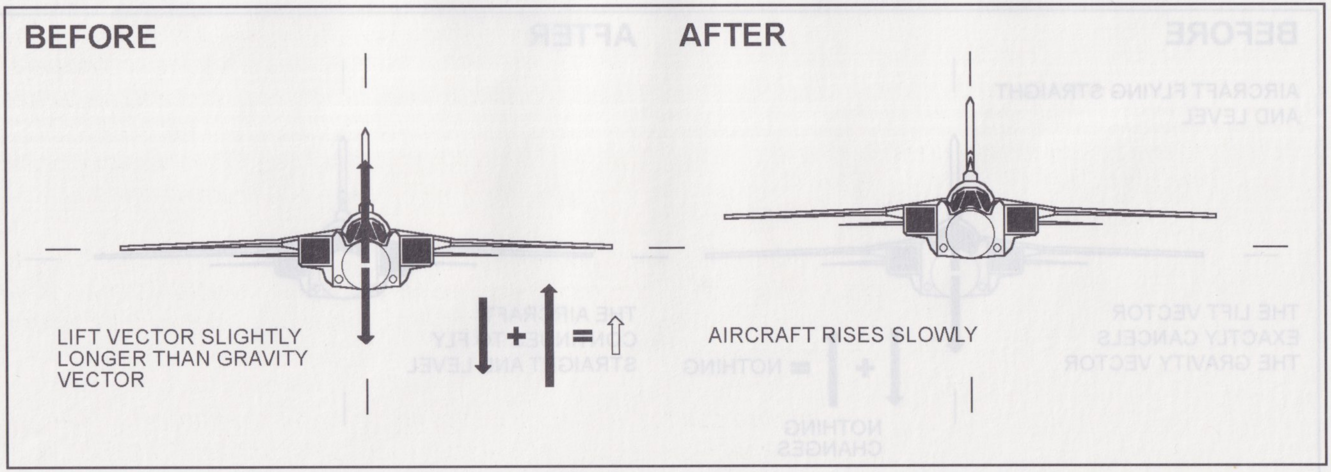
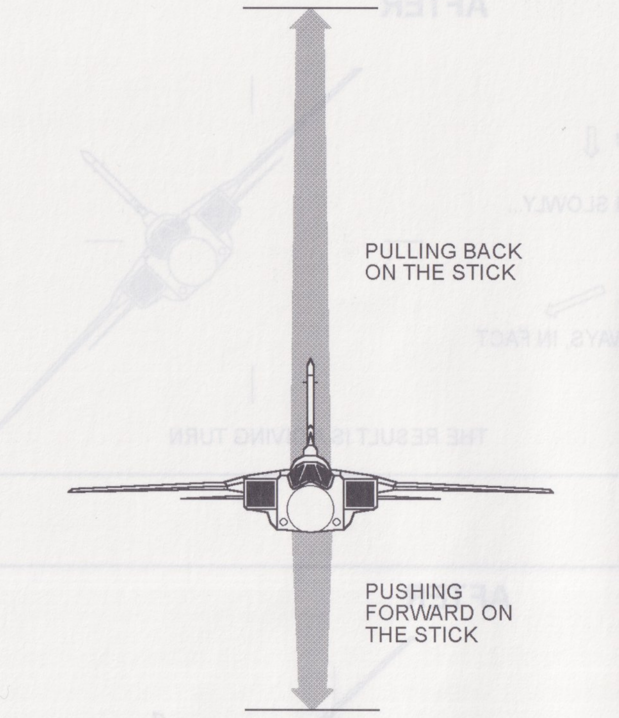


diagram 7.9



The Lift Vector changes length and direction as you pull or push on the control stick

diagram 7.10

If the length of the Lift Vector is less than the length of the Gravity Vector, then the force acting up is less than the force acting down, and the aircraft will slowly sink *(diagram 7.8)*. If the force acting up is greater than the force acting down, the aircraft will rise *(diagram 7.9)*. How fast it will rise or sink depends on the size of the difference between the two forces. When you pull back on the control stick, you are making the Lift Vector longer. When you push forward on the control stick, first you shorten the Lift Vector, and then if you keep on pushing, you reverse its direction and increase its length that way *(diagram 7.10)*.

Now let's look at what happens when the aircraft banks *(diagram 7.11)*. The Gravity Vector always points straight down, but the Lift Vector rolls with the aircraft. It always acts at a right-angle to the wings when you're looking at the aircraft from in front. The length of the Lift Vector hasn't changed, but its direction is no longer exactly opposite to the direction of the Gravity Vector, so only some of the lift force is opposing the Gravity Vector - the rest is turning the aircraft and dragging it sideways. Because the Lift Vector is no longer cancelling out the full force of the Gravity Vector, the aircraft starts to sink, and in the resulting imbalance of forces the nose drops and the aircraft dives more and more steeply.

Pulling back *(diagram 7.12)* lengthens the Lift Vector, so that the fraction of its force opposed to the Gravity Vector is enough to counteract it entirely. This means that the sideways force is greater too, so the turn also speeds up.

You can also see that the steeper the angle of bank, the harder you need to pull to maintain level flight, and the faster you turn *(diagram 7.13)*. How hard can you pull? The Tornado's wings are built to support 7.5 times the aircraft's

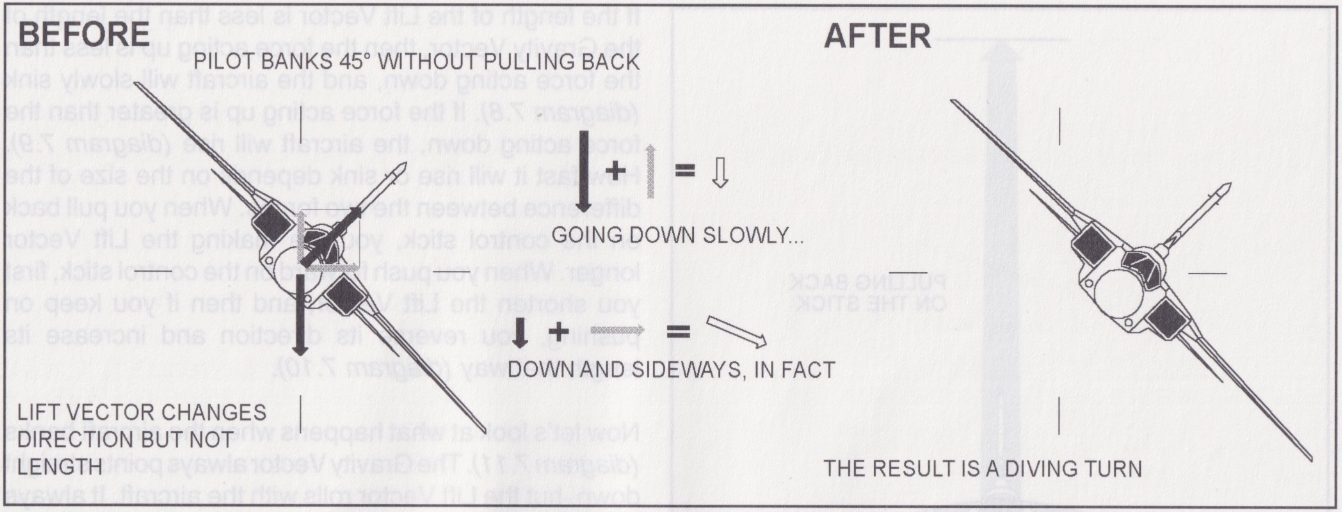


diagram 7.11

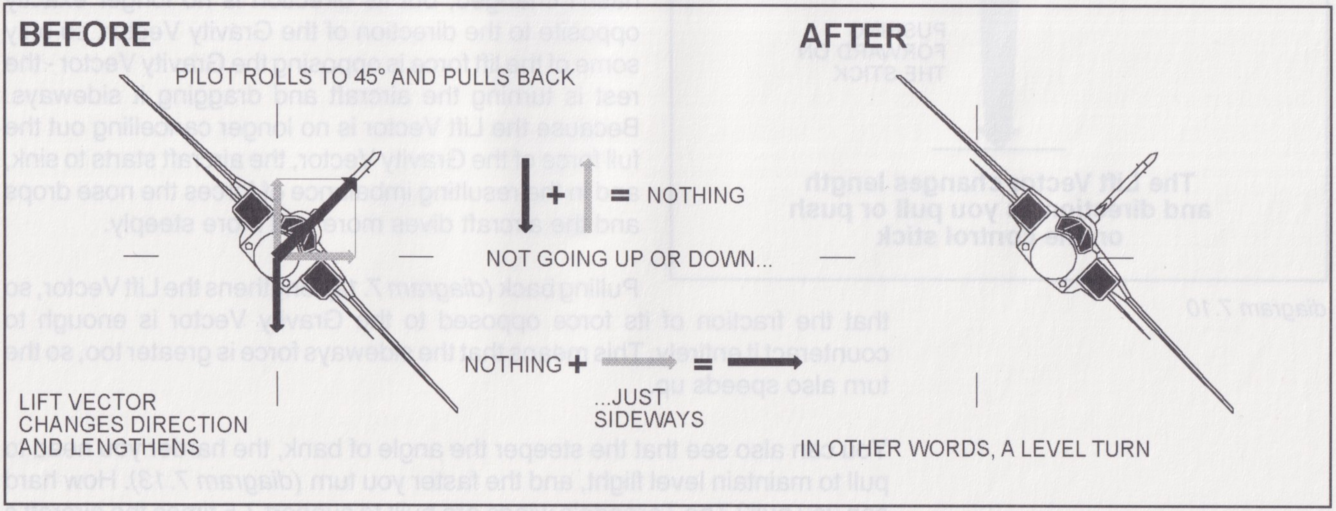


diagram 7.12

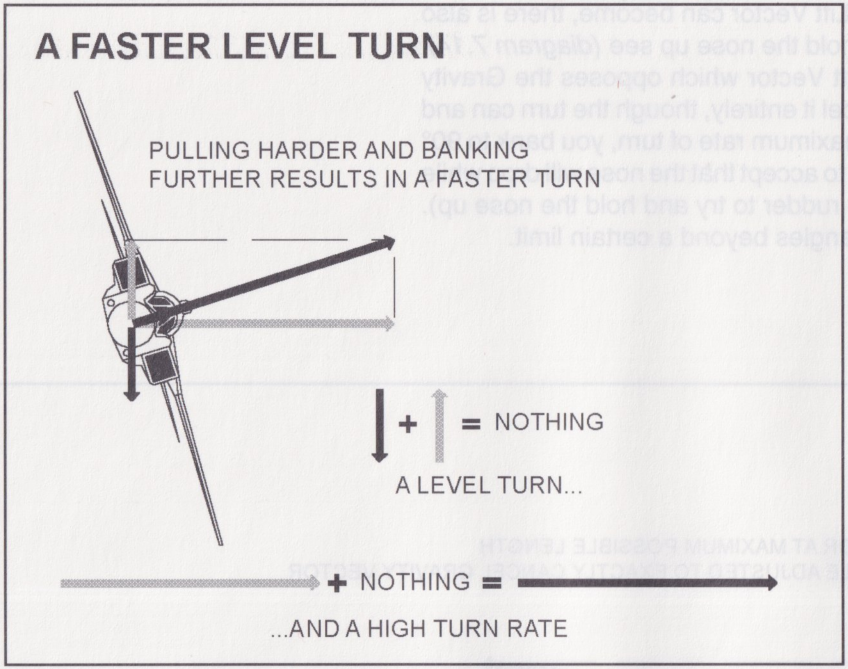
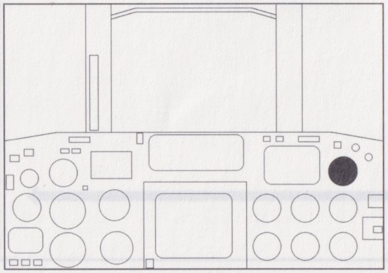


diagram 7.13

weight as a safe maximum, so at most you can make the Lift Vector seven and a half times longer than the Gravity Vector. The flight control system knows about this limitation, and won't allow you to pull hard enough to break the aircraft.

Positive G and G-LOC

As you may have realised, if you're pulling this hard, you, the pilot, are being pushed down into your seat with 7.5 times the force of gravity. Lifting a hand - or even supporting your head upright - takes seven and a half times more effort than usual. Even worse, your heart and circulation are struggling to pump blood 'uphill' to your brain and slowly losing the battle. If you keep this up for too long, you will black out. Since this usually means that you stop pulling, the force becomes less, blood returns to your brain, and you wake up again - unless, of course, you've crashed or been shot down meanwhile. The situation is sometimes known as G-LOC: G-induced Loss Of Consciousness. The G stands for Gravity - but here it's just being used as a unit of measurement. If you're pulling hard enough to make the Lift Vector 7.5 times as long as the Gravity Vector, we say that you're pulling 7.5 G. You and the aircraft are experiencing 7.5 times the normal force of gravity.


G Meter

The G-force reading is shown on the G-meter (upper right centre) on the instrument panel. In the Simulator you can ignore G-LOC if you wish, by using the switch on the Mission Selection Screen to disable it. In the real world this desirable option is unfortunately not available.

Because there is a limit to how long the Lift Vector can become, there is also a limit to how far you can bank and still hold the nose up see *(diagram 7.14)*. Beyond this angle, the fraction of the Lift Vector which opposes the Gravity Vector can never be long enough to cancel it entirely, though the turn can and will get faster. If you want the absolute maximum rate of turn, you bank to 90° and pull as hard as you can, but you have to accept that the nose will drop while you're doing it (unless you use opposite rudder to try and hold the nose up). This is why Autotrim can't handle bank angles beyond a certain limit.

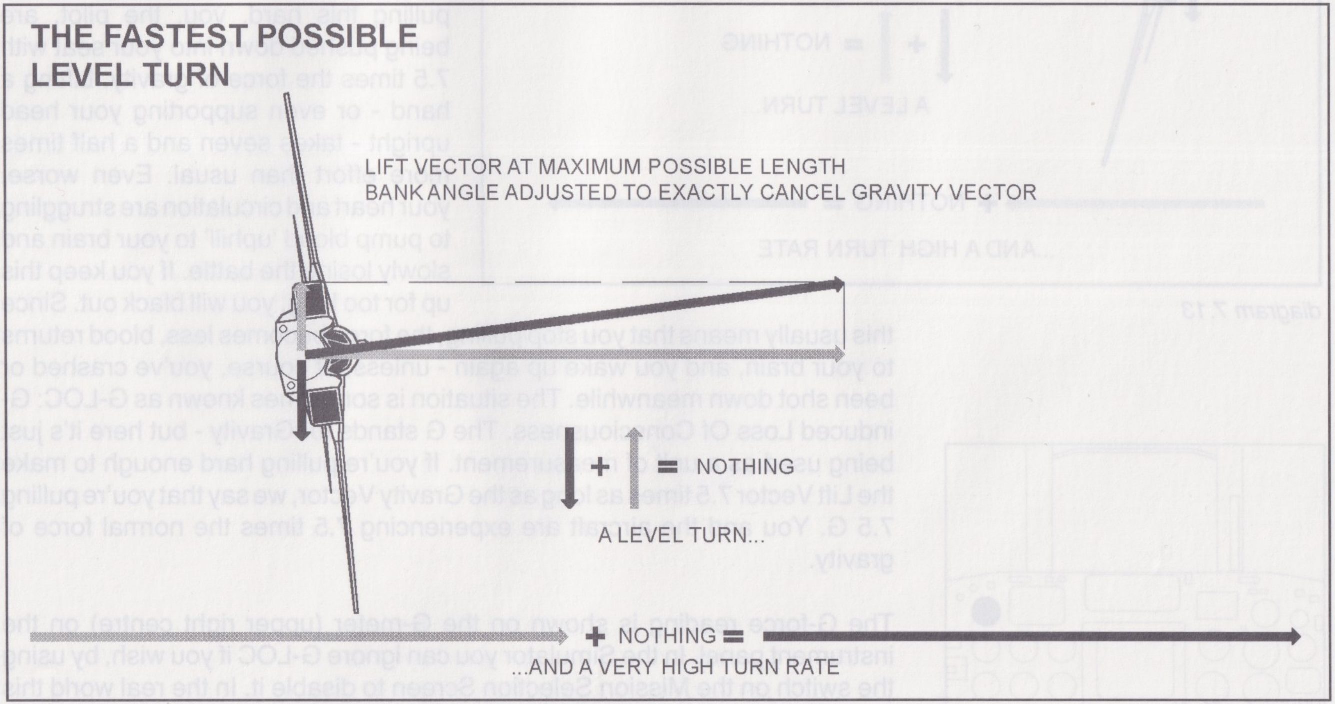


diagram 7.14

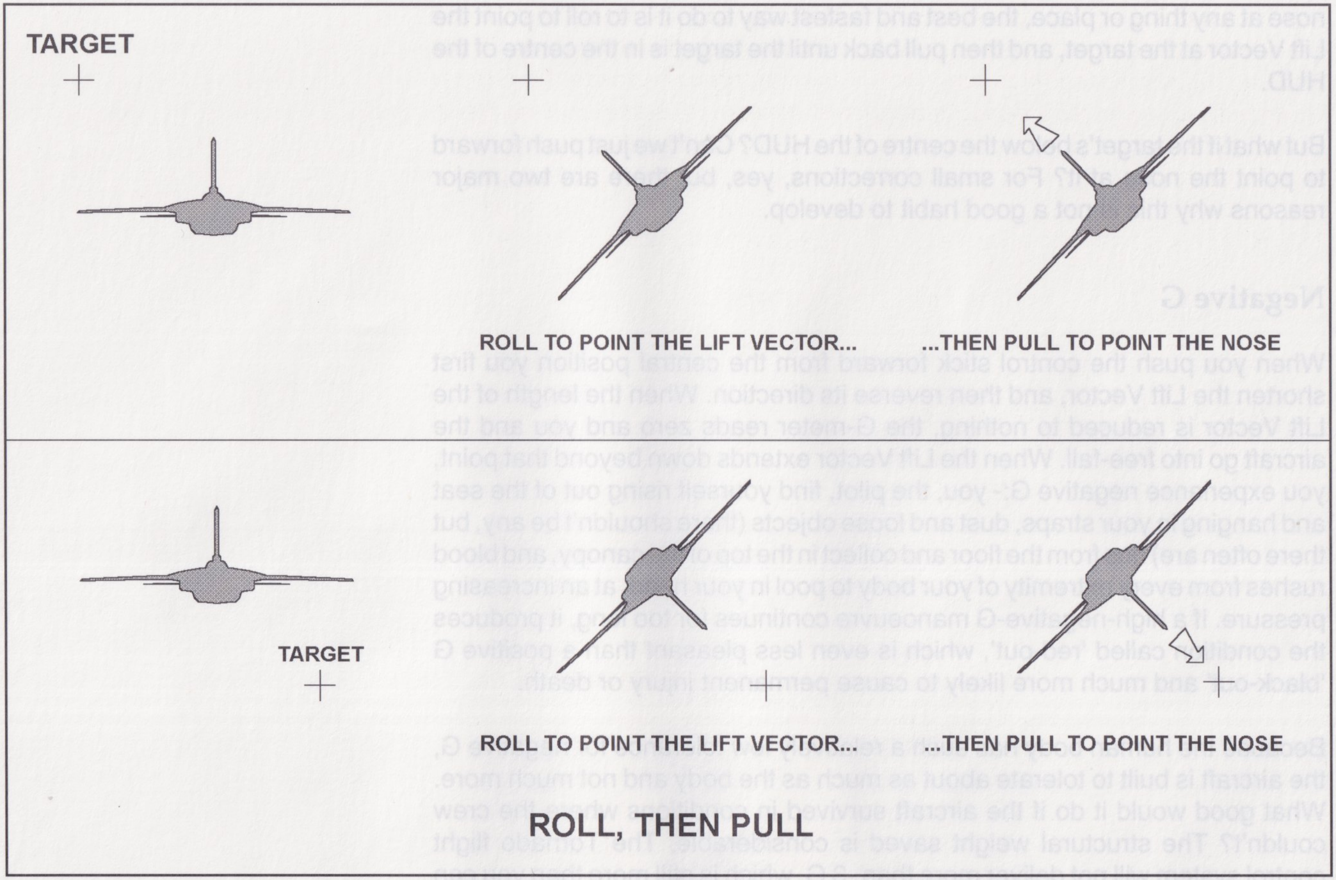


diagram 7.15

Pointing the Nose: ROLL, then PULL

The idea of the Lift Vector is important for every kind of manoeuvre, not just level turns. Imagine a line running straight up from the centre of the HUD, pointing in the same direction as the Lift Vector, so that as the aircraft rolls, the line still points straight up the HUD. In general, if you want to point the aircraft

nose at any thing or place, the best and fastest way to do it is to roll to point the Lift Vector at the target, and then pull back until the target is in the centre of the HUD.

But what if the target's below the centre of the HUD? Can't we just push forward to point the nose at it? For small corrections, yes, but there are two major reasons why this is not a good habit to develop.

Negative G

When you push the control stick forward from the central position you first shorten the Lift Vector, and then reverse its direction. When the length of the Lift Vector is reduced to nothing, the G-meter reads zero and you and the aircraft go into free-fall. When the Lift Vector extends down beyond that point, you experience negative G:- you, the pilot, find yourself rising out of the seat and hanging in your straps, dust and loose objects (there shouldn't be any, but there often are) rise from the floor and collect in the top of the canopy, and blood rushes from every extremity of your body to pool in your head, at an increasing pressure. If a high-negative-G manoeuvre continues for too long, it produces the condition called 'red-out', which is even less pleasant than a positive G 'black-out' and much more likely to cause permanent injury or death.

Because the human body has such a relatively low tolerance for negative G, the aircraft is built to tolerate about as much as the body and not much more. What good would it do if the aircraft survived in conditions where the crew couldn't? The structural weight saved is considerable. The Tornado flight control system will not deliver more than -3 G, which is still more than you can sustain for long without red-out.

When you're flying straight and level and you want to dive, the obvious way to do this is to push the control stick forward to lower the nose. For small corrections this is a perfectly valid method, but pushing forward to enter a steep dive is not a good idea. The risk of red-out is one excellent reason to avoid this practice, the other is that it's a slow way to manoeuvre - just not good enough in combat.

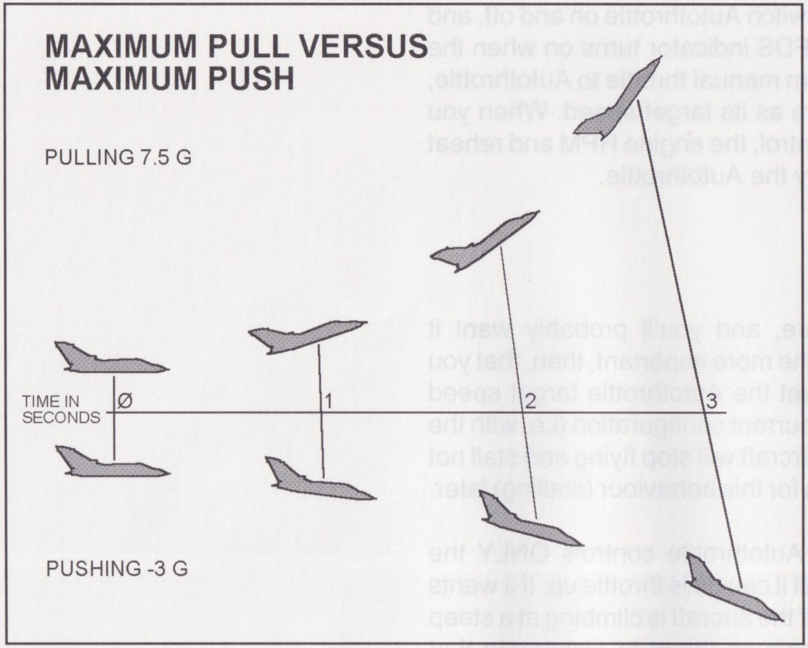


diagram 7.16

The reason it's slow is because the aircraft's negative-G limit is less than its positive-G limit: -3 G against +7.5 G. You've already seen how the length of the lift vector governs the turn rate, and there's very little difference between a steep hard turn and a hard climb or dive: the force of gravity makes some difference but not a lot when the Lift Vector is up to 7.5 times longer. *Diagram 7.16* gives some idea of the maximum turn rates available by pulling +7.5 G as against pushing -3 G.

In the light of this, use the method described above - ROLL to line up the Lift Vector and then PULL to point the nose - for all but the smallest corrections. If this leaves the aircraft pointed in the right direction but flying upside-down, just roll it upright again.

THE AUTOTHROTTLE

If you haven't already done so, hit F8 again for Heading and Altitude Hold, and watch the HUD Airspeed figure until it becomes steady. All this time you've been flying with the engines under control of the Autothrottle, which is throttling the engines to try and maintain the requested Indicated Air Speed, which is shown on the AFDS display on the MFD.

Just as the control stick (which flies the aircraft manually) is used to change the autopilot's orders when the AFDS is flying the aircraft, so the throttle controls (which normally vary the engine RPM manually) are used under Autothrottle to change the desired speed up and down. Look up the Throttle Controls on the Control Summary. On most machines they will be the + and - keys on

the numeric keypad. The [F10] key is used to switch Autothrottle on and off, and the yellow indicator light next to the green AFDS indicator turns on when the Autothrottle is engaged. When you switch from manual throttle to Autothrottle, it takes the current Indicated Air Speed figure as its target speed. When you switch from Autothrottle to manual throttle control, the engine RPM and reheat settings stay at the last value commanded by the Autothrottle.

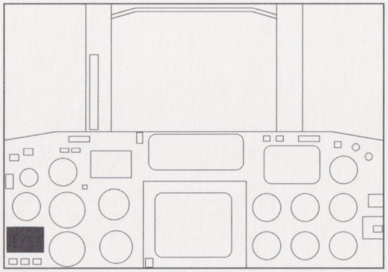
Limits of the Autothrottle

Autothrottle is an enormously useful feature, and you'll probably want it switched on most of the time you're flying. All the more important, then, that you learn its limitations. For the moment, don't set the Autothrottle target speed below about 250 knots - with the aircraft in its current configuration (i.e. with the wings swept back as far as they will go), the aircraft will stop flying and stall not far below this speed. We'll look at the reasons for this behaviour (stalling) later.

Other limitations exist mainly because the Autothrottle controls ONLY the throttles. If it wants to accelerate the aircraft, all it can do is throttle up. If it wants to decelerate, all it can do is throttle back. But if the aircraft is climbing at a steep angle, the engines simply cannot develop enough thrust to accelerate that much weight 'uphill', or even prevent the speed from dropping. If the aircraft's nose is pointed down in even a moderate dive, the aircraft will accelerate as it coasts 'downhill' even though the Autothrottle has cut the engines back to idle thrust (63% RPM).

You can cope with the first situation (the climb) either by climbing at a gentle angle which the engines can sustain (generally less than 20° nose-up) or by accelerating to a high speed in level flight before pulling back into a steep climb (a 'zoom climb'). In this case you will lose speed in the climb, but you started with a high speed, so you can carry on climbing for some time before the speed falls to a dangerously low figure.

To handle the second situation (unwanted acceleration in a dive), use the Airbrakes. Look it up in the Control Summary, but on most machines the key

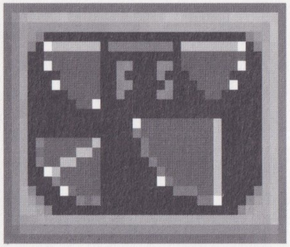


Secondary Control Surfaces Position Indicator

will be [Backspace]. While you hold this key down, the Airbrakes, which are large panels on the upper rear fuselage, are swung open to increase drag and slow you down. If you look at the Airbrake Position Indicator (lower left on the Panel) you'll see a needle flick in and out as you deploy and close the Airbrakes. This technique will work for moderate dive angles, but there is a limit to the effect. If you think about it, you can see that it would take an extremely large parachute to do very much for a 45000 lb. (22000 Kg.) aircraft in a vertical dive!

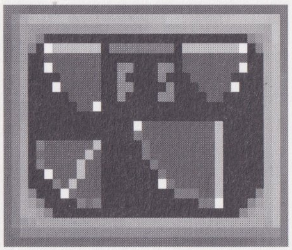
Manoeuvre Drag

There is another source of drag which can make it impossible for the Autothrottle to maintain its target speed, and this is the drag caused by manoeuvering. When you pull back hard on the stick you are forcing the wings to generate a large amount of lift, but it is impossible to do this without also generating a large amount of drag (though the proportion of drag to lift varies with the wing sweep setting - see later). If you set the aircraft up in level flight at a constant speed under Autothrottle and then enter a steep hard turn, you will see the Airspeed start to decay, while the Autothrottle cuts in maximum thrust and still can't keep up.



Airbrake on

While this increased drag and loss of speed is usually a severe nuisance in air-to-air combat manoeuvres, it does have a practical use if you want to slow down in a hurry. Turning hard is probably the best way of losing a lot of speed quickly - even more effective than the Airbrakes.



Airbrake off

There is one more corollary of the relationship between lift and drag. If more lift means more drag, less lift means less drag, and presumably zero lift means zero drag! Unfortunately drag comes in many flavours and the drag due to lift is not the only form of drag affecting the aircraft, but it is possible to improve your acceleration by pushing forward till the G-meter reads 0. This manoeuvre can be important when you need to run away from a fighter or a missile, and is generally called 'unloading', but if you keep it up for too long you'll dive into the ground. We should also point out that negative lift unfortunately does not imply negative drag!

STALLING

Several times above you will have seen the caution; don't let the aircraft's speed drop too low, or it will stop flying. Now we're going to show you what happens next and why. Since stalling behaviour is so heavily related to airspeed, we'll start by explaining just what we mean by 'Indicated' Air Speed.

Indicated Air Speed - IAS

Indicated Air Speed (IAS) is one of four common ways of expressing an aircraft's speed. The others are True Air Speed (TAS), which represents the speed relative to the air you're flying through, Ground Speed, which is actual speed over the ground, and Mach Number, which represents your speed as a multiple or a fraction of the speed of sound at your current altitude. So what can IAS be if it's not the same as any of these?

At ground level Indicated Air Speed is exactly the same as True Air Speed: speed through the air. As the aircraft climbs, however, the outside air pressure and density fall. The higher you go, the thinner the air. The amount of lift generated by your wings depends largely on the speed and density of the air flowing over (and under) the wing. At higher altitudes and lower air densities you need to fly faster just to stay in the air. The Indicated Air Speed figure takes air density into account, and so for any given aircraft weight, wing sweep and flap setting the aircraft will always stall (i.e. stop flying) at the same IAS. If the pilot used a TAS figure the stall speed would increase with altitude, which would be confusing and dangerous.

At ground level an Indicated Air Speed of 200 knots means that your True Air Speed is 200 knots. At 30000 feet, an IAS of 200 knots means that your TAS is about 327 knots. In both cases you can look at the IAS figure and know that your speed is dangerously low - in fact, with wings fully swept back, the Tornado would quite possibly have stopped flying and started falling at 200 knots IAS.

Angle of Attack

Lift can also be varied more directly by changing the angle at which the wings meet the airflow (the Angle of Attack, aka Alpha angle). *Diagram 7.17* shows how this angle is defined. Suppose your aircraft is flying straight and level. If you now raise the nose slightly, that will generate more lift, and the aircraft will climb. The problem is that tilting the wings at an angle to the airflow generates more drag as well as more lift, and either the engines must produce more thrust or the aircraft will slow down. The steeper the angle of attack, the more lift and the more drag produced.

The trouble is that your wing only generates lift when air is flowing smoothly round it on both surfaces. If the Angle of Attack increases too far, the airflow over the upper surface simply cannot follow the wing surface. It breaks away and becomes turbulent - and the wing suddenly ceases to generate any useful quantity of lift. This is the STALL condition, where the aircraft stops flying and starts falling. At this point you lose most flight control because there just isn't enough air flowing over the control surfaces to make them effective. If the aircraft is left to its own devices at this point, the nose will drop, the aircraft will accelerate as it falls, and it will usually regain flying speed within a few seconds. This is fine if nobody's shooting at you, and you can afford to lose the height. If you can't (for example, at 200 feet while approaching to land), it can be lethal, so you must know how to avoid stalling if possible, and how to handle the situation if not.

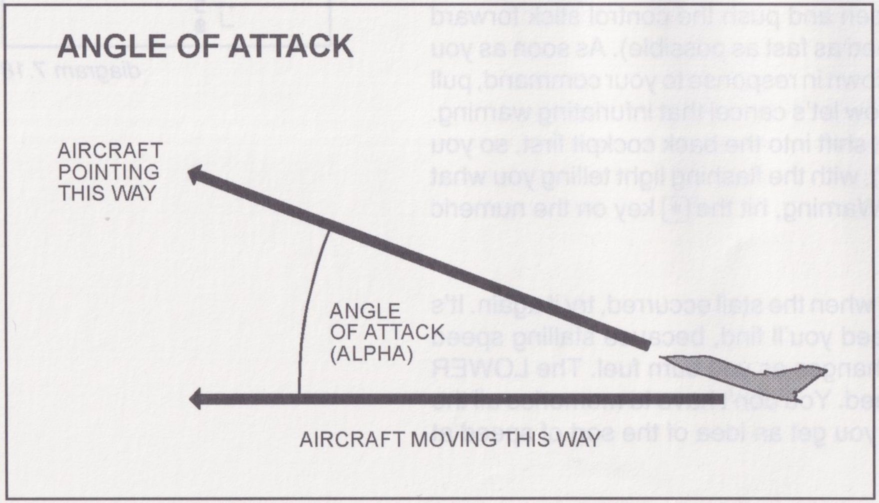
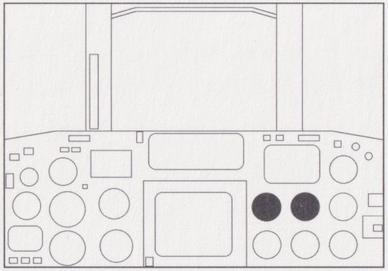


diagram 7.17

Use the AFDS in Altitude and Heading Hold mode to set the aircraft up in straight and level flight at an altitude

of at least 8000 feet, with the autothrottle at about 400-450 knots. When you've done this, turn the Autothrottle off by hitting F10, but leave the autopilot engaged. Look in your Control Summary and find the throttle 'Slam Shut' and 'Slam Open' commands. Use 'Slam shut' to bring the engines down to idle thrust - you should see the RPM gauges drop to a figure of 63%.



Engine r.p.m. Gauges

Now watch the HUD Airspeed Indicator, the Pitch Ladder, and the vertical strip meter on the left side of the HUD, opposite the VSI. This is the Angle-of-Attack (Alpha) meter *(diagram 7.18)*. With the engines idling, the airspeed will drop, but you may want to use the Airbrakes carefully to bring your speed down to about 250 knots - let your speed decay naturally from that point. You should see that as the speed drops, the autopilot maintains the set altitude. In order to do so it raises the nose more and more, which will show up on the Pitch Ladder. At the same time the Alpha meter shows a steadily rising trend.

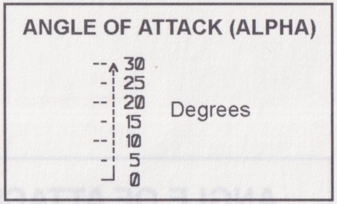


diagram 7.18

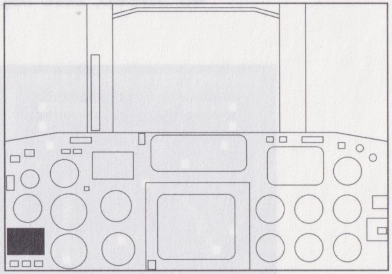
Finally the stall point is reached, the nose drops uncontrollably. The AFDS system realises that it can't handle the situation and turns itself off - and tells you so by sounding an alarm and flashing the Attention-Getter lights. Now it's time for you to act: slam the throttle open and push the control stick forward (you're trying to accelerate to flying speed as fast as possible). As soon as you see that the aircraft is actually pitching down in response to your command, pull the stick back GENTLY and level off. Now let's cancel that infuriating warning. You can do this from either cockpit, but shift into the back cockpit first, so you can see the Warning Panel (lower right), with the flashing light telling you what the warning was about. To cancel the Warning, hit the * key on the numeric keypad or the ' key.

If you didn't notice the airspeed reading when the stall occurred, try it again. It's impossible to tell you exactly what speed you'll find, because stalling speed varies with the aircraft weight, which changes as you burn fuel. The LOWER the weight, the LOWER the stalling speed. You don't have to memorise all the possible values, but it's important that you get an idea of the sort of speed at which you're likely to run into trouble.

Once you understand what causes a stall and how to recover from it, the aim is to be able to recover while losing the absolute minimum of height. It is crucial to be able to do this if you stall while taking off or landing. The indispensible factor for recovery is Airspeed - the faster you accelerate, the faster you recover, but if that recovery involves pointing the nose straight down for maximum acceleration, then you're going to lose a lot of height. You will generally find that because the nose falls of its own accord you need not push forward to lower it; the really vital action is opening the throttles. Open them right up to Combat Power (Max Reheat), which may be done fastest by using Slam Open, releasing the throttle control (stick or key), and then using Slam Open again. Just remember to shut off Reheat once you have reached a comfortable speed (Slam Shut while in reheat cuts the throttles back to maximum RPM dry), because fuel consumption at max Reheat is appalling, especially at low altitude.

WING SWEEP

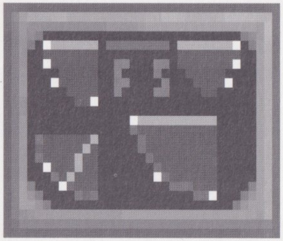
Assuming that you're back in control, set an altitude of 8000', and let's try something a little different. Make sure that your speed is less than 500 knots and steady. Now look in the Control Summary for the Wing Sweep controls (W and S on most machines) and find the Wing Sweep Position Indicator (lower left on the Panel). The indicator should show that the wings are at maximum sweep (67° sweep). Hit the F2 key for Satellite View to see the aircraft from outside and above so that you can see what this looks like. Go back to the Front Cockpit and hit the W key once. You should see the Wing Sweep Indicator needle move forward to the mid-sweep (45° sweep) position. When the needle has finished moving, flip back to the Satellite view so you can see what this looks like.


Secondary Control Surfaces Position Indicator

Now try the stall again, watching the airspeed and the Alpha meter, and recover as before, ensuring that you return to a steady speed no higher than about 500 knots. You should find that the stalling speed is noticeably lower than it was at full sweep, but the behaviour of the Alpha meter looks much the

same - it rises as the speed falls off and the nose rises, and the stall occurs not long after it reaches a point just beyond the fourth marker on the scale of dots. If you try some turns you should also find that the aircraft manoeuvres more crisply and turns faster than it did at full sweep.

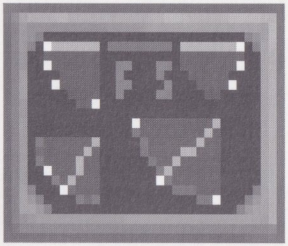
Set Autothrottle and reduce your speed to about 350 knots indicated. Hit the W key again to sweep the wings all the way forward to 25° sweep. Go through the stall routine again and you will find that the stalling speed has dropped once more. Turns will reveal that the aircraft feels even more nimble than it did at mid-sweep.



25° sweep, zero flap

This series of tests should have convinced you of a number of things:

- The further forward the wings are swept, the lower the stalling speed.
- The further forward the wings are swept, the better the aircraft turns.
- Whatever the sweep angle, the Alpha Meter is a more consistent indicator of an approaching stall than the Airspeed Indicator.



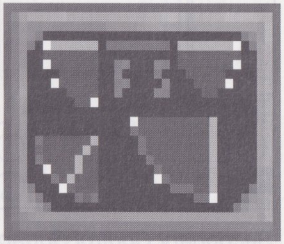
45° sweep, zero flap

The conclusion is obvious - if you're flying slowly, or you need to turn as tightly as possible, sweep the wings forward. You can reduce the stalling speed even more by lowering the Flaps as well, but we'll come to that later.

So why bother with sweeping the wings back, if the aircraft flies better and more safely with the wings forward? Let's demonstrate.

Mach Number

Starting with the aircraft flying level at about 5000 feet with 25° sweep at about 400 knots under Autothrottle. Check that you know how to sweep the wings back again (usually the S key). Now set the Autothrottle for about 480 knots and watch carefully as the aircraft accelerates. Before you've reached the target speed you'll hear a rumbling, buffeting noise and possibly notice some vibration. When you do, sweep the wings back to the mid-sweep position and the buffeting should stop.



67° sweep, zero flap

You've just run into what are called compressibility effects - the fringes of what used to be called the Sound Barrier. Though the aircraft as a whole is nowhere near the speed of sound yet, the airflow over parts of the wings was beginning to approach sonic speeds at different places at different times. Shockwaves are constantly forming and collapsing in a chaotic pattern, causing turbulence and shaking the aircraft. If you had carried on accelerating without sweeping the wings back, the effect would have grown more severe, and eventually the aircraft would become uncontrollable and/or shake itself to pieces. Sweeping the wings back delays the formation of the shockwaves until you reach a higher speed.

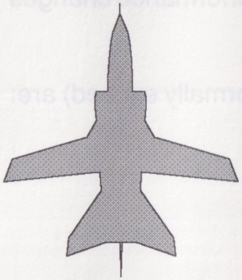
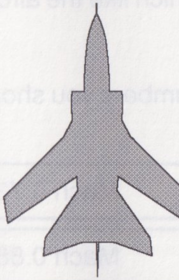
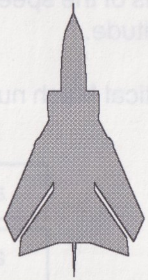
	25 SWEEP	45 SWEEP	67 SWEEP
CONFIGURATION			
MANOEUVRABILITY	BEST	FAIR	WORST
STALLING SPEED	LOWEST	MEDIUM	HIGHEST
LIMITING SPEED (MACH NUMBER)	LOWEST (0.73)	MEDIUM (0.88)	HIGHEST (2.2+)

diagram 7.19

Now set the autothrottle for about 600 knots. Once again, as the aircraft accelerates, you will hear and/or see buffeting, which will disappear if you sweep the wings back all the way to 67°. You can now accelerate past the speed of sound (Mach 1) all the way to the limits of the aircraft's performance at the current altitude before you will experience any further buffeting.

So now you know why variable-sweep wings are such an attractive idea. Low sweep angles allow a low stalling speed, so the aircraft can land more slowly and stop on a shorter runway. They also make the aircraft more agile. High sweep angles are not so good for manoeuvre, but they do allow you to reach high speeds. We'll go a little further into the subject later. For the moment, the important thing is to give you an idea of the speed limitations of each sweep setting. Because those limits are intimately related to how closely you approach the speed of sound, the best way to express them is as Mach Numbers; fractions of the speed of sound, which like the aircraft's performance changes with altitude.

The critical Mach numbers (the numbers you shouldn't normally exceed) are:

at 25° sweep:	Mach 0.73
at 45° sweep:	Mach 0.88
at 67° sweep:	Mach 2.20

You can switch the HUD airspeed indication from knots IAS to Mach number or back using Alt H. Here are some figures to give you some idea of the relationship between True Air Speed, Indicated Air Speed and Mach Number at different altitudes (see table opposite).

Like any other fast jet, the Tornado's top speed depends on how high it's flying. At sea level the high drag due to high air density means that the aircraft can make 800 to 850 knots (Mach 1.21 - 1.29) flat-out, depending on the weight,

Altitude (feet)	TAS (knots)	IAS (knots)	Mach Number	Mach 1 (speed of sound) is: TAS	IAS
0	500	500	0.76	661	661
5000	500	464	0.77	650	603
10000	500	430	0.78	638	549
15000	500	396	0.80	626	496
20000	500	365	0.81	614	448
25000	500	334	0.83	602	403
30000	500	306	0.85	589	360
35000	500	278	0.87	576	321

which is still faster than any other aircraft flies at that height. At high altitude (say 36000 feet), the limit is roughly Mach 2.2, which is about 1262 knots TAS, 689 kts. IAS. This is clearly not slow, but most fighters are faster than this at these altitudes. The obvious moral is: if you have to run away from a fighter, do it as low down as possible.

Now that you have some idea of how to fly, and what to do about stalls, let's try something a little more challenging - landing.

AUTOMATED LANDINGS

Landing is the most difficult of ordinary flight manoeuvres, but the Tornado's AFDS can do a great deal to make it easier. In order to achieve a successful landing, you must do the following four things in this order:

1.You must arrive at a suitable point to start your approach to the runway at a sensible speed and pointing in approximately the right direction.

The Mission Planner systems will normally be helping you plan to do this, and the AFDS in Track mode will get you there if necessary. We'll look at this in more detail in Advanced Flying Training.

2. You must fly the approach to the runway accurately while decelerating, sweeping the wings forward and lowering the flaps and landing gear, so as to arrive at the runway threshold just above the ground, flying as slowly as safely possible in the right direction.

The AFDS in Approach mode will fly the approach path for you and manage the throttle. All you will have to do is deploy airbrakes, wing sweep, flaps and gear at the appropriate times.

3. Just before the aircraft touches down you must 'flare', raising the nose and/or throttling up to reduce the rate of descent to a figure the gear legs and tyres can take comfortably.

The AFDS won't do this for you, but it's not too difficult.

4. Having touched down, you must slow the aircraft so that you can turn off the runway, or stop, before overrunning the end.

This you will have to do for yourself, and it's high-pressure work, but quite mechanical. Overrunning an 8000' runway takes some doing, but being able to land and stop short on a damaged runway can save you and your aircraft in wartime.

For the moment, all you're going to do is learn to use the AFDS to fly the approach for you, and then how to handle the necessary manual tasks at touch-down and just after.

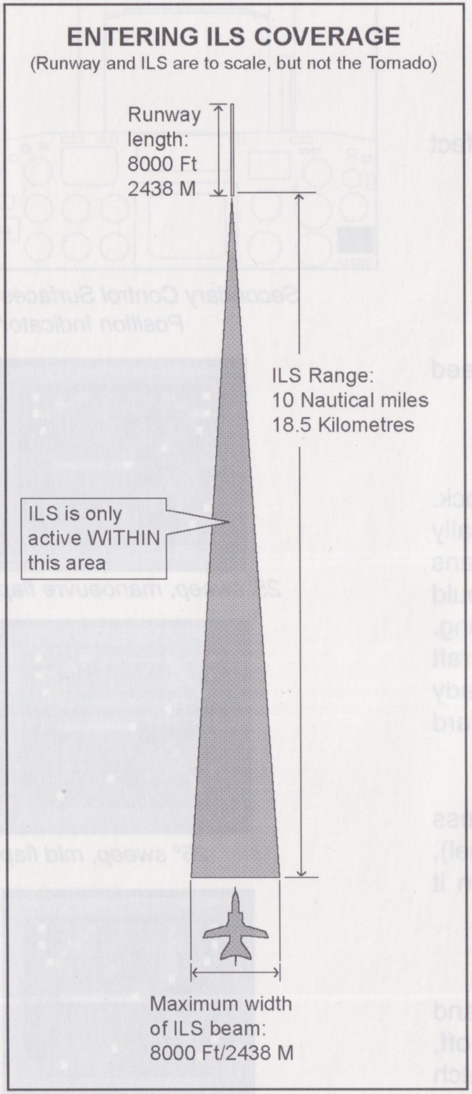


diagram 7.20

Landing Practice for Auto-Approach

From the Main Screen, select Flight, then Simulator. From the Simulator Missions, select 'Landing Practice'. Having clicked on 'Commit', you will find yourself in the cockpit. Hit the Pause key. You are straight and level at 4000 feet ASL heading towards a runway, just outside ILS (Instrument Landing System) range, with autothrottle set at 450 knots and wings at 45 sweep. The HUD shows the standard nav display.

Unpause and wait a few seconds. As you come in range of the ILS system, you'll see the HUD symbology change - the centre symbol becomes a small open cross, and a larger open cross appears off-centre. This will always happen when you enter range of an ILS system if the HUD is in nav mode (i.e. not a weapon aiming mode). Take a look at *diagram 7.20*, which shows your situation in plan view. The sequence of operations from here should go like this - you may want to use the Pause key to stay ahead of the instructions:

Hit Key - AFDS Approach Mode. (F6)
The aircraft will start manoeuvering to put the large cross on the HUD in the centre WITH the aircraft on the runway heading. The throttles will also be adjusted as the autothrottle seeks the correct approach speed for the aircraft weight and configuration. The aircraft should start to slow down.

Hit/Hold Key - Airbrakes
Use Airbrakes to bring the speed down to 350 knots.

Hit Key - Sweep Forward (to 25 sweep)
As you do this you should see the throttles close briefly. You've just lowered the stalling speed, so the AFDS can fly the approach more slowly.

Hit Key - Flaps Down
Do this once, for the moment, to lower Manoeuvre Flap. You will see the Flap/Slat position indicators droop to the first position.

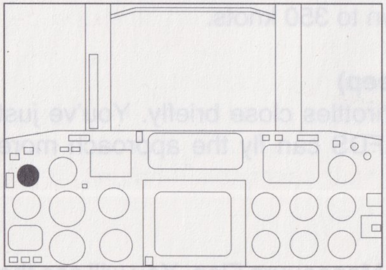
Hit/Hold Key - Airbrakes
Bring your speed down to less than 280 knots.

Hit Key - Flaps Down
Now you're below the limiting speed for Mid Flap. This will have a large effect on the stalling speed, so you should see the throttles close again.

Hit/Hold Key - Airbrakes
Bring your speed down to less than 225 knots.

Hit Key - Flaps Down
Now you're slow enough for Full Flap, which will bring your approach speed down to the slowest possible.

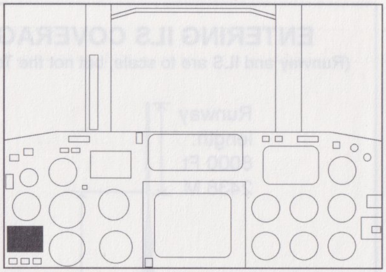
Hit Key - Gear Switch
Watch the Gear Indicator lights to make sure it does come down and lock. Initially there will be no lights, then three reds as the gear travels, then finally three greens to show that all three legs are locked down. Anything else means trouble. Putting the gear down creates a lot of extra drag, so the aircraft should be slowing rapidly if it has not already reached the autothrottle speed setting. If the throttles are still closed at this point, use the Airbrakes to slow the aircraft still more, until the engine RPM gauges rise from idle thrust and reach a steady value. You should now be in a stable approach, descending smoothly toward the runway.



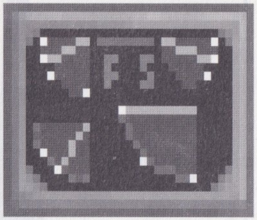
Gear Position Indicator

Now look for the Approach Progress Indicator light (upper right on the panel), and wait for it to start flashing. When it does...

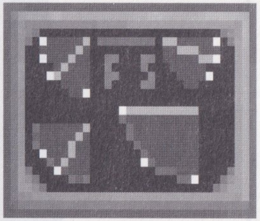
Hit Key - Cancel Autopilot
The aircraft should continue stably and smoothly down the approach, hands-off, since everything is already set up. Watch the HUD Altimeter as you approach the



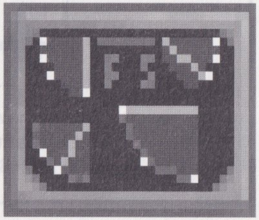
Secondary Control Surfaces Position Indicator



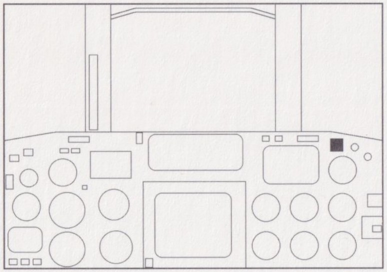
25°sweep, manoeuvre flap



25° sweep, mid flap



25° sweep, full flap

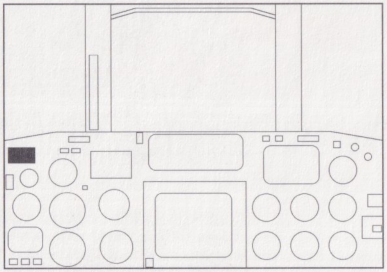


Approach Progress Indicator

runway threshold, and as the figure reaches 50 feet, start pulling back gently on the stick, until you can see the rate of descent start to slow down. Try to avoid going back up!

Ideally, you will descend most of the way to the runway fairly rapidly, and take just the last ten feet or so more slowly. As the main gear touches down (you should hear and see the thump, as well as the 0 reading on the HUD altimeter), release the stick and...

Hit/Hold Key - Thrust Reversers
The Thrust Reverser buckets close over your engine nozzles and divert thrust forward, slowing you down. Watch your airspeed, and at about 70 knots..

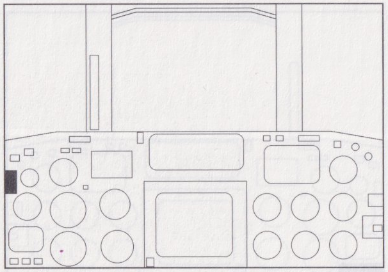


Thrust Reversers

Hit Key - Slam Throttle Shut

Release Key - Thrust Reversers

Hit Key - Wheelbrakes
You must disengage the Thrust Reversers before your speed drops below about 50 knots, or your engines will start re-ingesting their own exhaust, which will do them no good at all. Close the throttle first, or you'll just accelerate again. By the time you reach these speeds, you can apply the wheelbrakes without fear of burning them out, and you should now coast gently to a halt, having used up very little runway.



Wheel Brakes

If you managed to do that all first time, congratulations. Whether you succeeded or not, you need to practise it some more. Over most of the approach, there are a fair number of things to do to set up the aircraft, but not too much time pressure. Just before touchdown, the time pressure suddenly becomes acute, and every action is critical - you must know the sequence of operations in advance, and mentally rehearse it in the final seconds. Eventually it will become automatic. When you've had enough, read on.

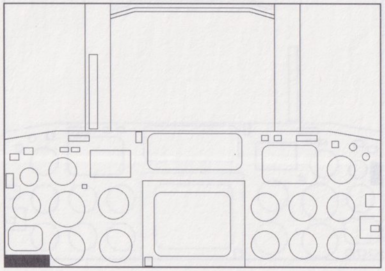
Heavier = Faster = Scarier

The aircraft weight affects your landing in two important ways. First, the heavier the aircraft, the higher the stalling speed - the faster it must fly just to stay in the air. The AFDS system knows this, and in Approach mode it sets the autothrottle speed setting to stalling speed plus a percentage. At higher weights, this obviously means that you touch down at higher speeds, and roll further before stopping. At maximum weight, even with wings fully forward, you will find that the AFDS wants to set the Approach speed at or above 225 knots - which is the limiting speed for Full Flap - leaving you in a complete Catch-22 situation: you've got to reduce the stalling speed (and therefore the approach speed) before you can deploy Full Flap, but the whole reason you want to lower Full Flap is to try to reduce the stalling speed!

The second difference weight makes is in how hard you can hit the runway without collapsing the gear. At light weight, with a nearly empty aircraft, the absolute limit is 20 feet per second, which is easy to achieve. Even though anything above 10 feet per second counts as a heavy landing, it isn't difficult beat this figure either. But at maximum weight, the absolute limit is one fifth of that - 4 feet per second. This is a far more difficult condition.

But what can I do about it?

There is a simple answer - dump some weight. The medium Jettison option (external tanks and air-to-ground weapons) will bring your weight down to a comfortable figure even if your internal tanks are still full. The maximum Jettison dumps most internal fuel as well, giving you a nearly empty aircraft. The section on Emergencies in the Advanced Flying Training chapter goes into this subject in more detail.



Jettison Lights

Operational Conditions

The Mission Planning software will always insist that a flight plan must include an Approach Point, located in a runway's ILS beam, and will ensure that you arrive at this point flying in the general direction of the runway. One further condition should also be satisfied - that you arrive at this point at a sensible speed, ideally no faster than 450 knots or so.

When you arrive at an Approach Point in Track Mode, the AFDS will automatically engage Approach Mode, and the aircraft will start to follow the ILS beam down to the runway. From this point on, the procedure is exactly the same as for the Landing Practice sequence. Provided that you stick to your flightplan and you can handle the last seconds of touchdown, landing should not be too much of a problem. In the next chapter, we will look at how to set up a landing anywhere you like, and do it manually.

TAKING OFF

Taking off is a far simpler manoeuvre than landing, you'll be glad to hear, but it involves using a lot of different controls in quick succession. It also helps if you have some idea of how to fly once you're in the air - and if you've followed through the exercises this far, now you do.

To get off the ground and stay in the air you'll need to know something about the following controls and instruments: (look them up in the Control Summary and the Aircrew Notes)

- Throttle Control, Engine Instruments
- Wheelbrakes Switch and Indicator
- Control Stick (Joystick/Keyboard)
- HUD Airspeed Indicator, Altimeter, VSI, Pitch Bars
- Landing Gear Switch and Indicator
- Flaps Up Switch and Flap Position Indicator

From the Main Screen select Flight, and then the Simulator. On the Mission Selection Screen, choose the option 'Free Flight (from runway)'. You will find yourself in the Mission Planner. If this is your first take-off, just click on the button marked 'Take-off', on the right-hand side. You will find yourself in the cockpit, on the runway, with engines idling and Medium Flap selected, all ready to go.

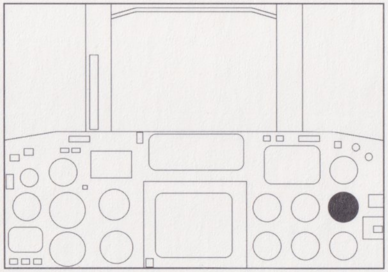
Step 1. Fully open the throttle. You'll see the Engine RPM gauges rise till they show 100%. At the same time, the Fuel Flow gauge will show a moderate rise. Now release the Throttle control. Light up Reheat (Afterburners), by fully opening the throttle again. The Engine RPM gauges will stay on 100%, but both Reheat Indicators will light, and the Fuel Flow gauge needle will spin clockwise and jam itself against the stop. The aircraft is now at absolute maximum power, held only by the brakes - you may notice some vibration.

Step 2. Release the Wheelbrakes, watching the indicator to make sure it goes out. The aircraft will start rolling.

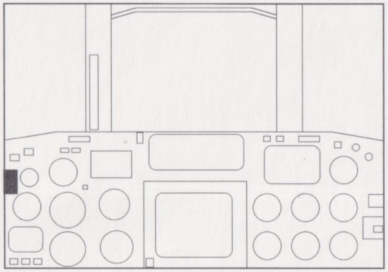
Step 3. Watch the HUD Airspeed Indicator, and stand by with the Control Stick. When the speed reaches 140 knots, pull the stick back and hold it back. If the aircraft is lightly loaded the nose will immediately start to rise, if it's heavy this won't happen until you have more speed. Hold the stick back until you're pitched up about 8-12° according to the HUD Pitch Bars, from just below to just above the first bar above the horizon. Now release the stick.

Step 4. Watch the HUD Altimeter. As soon as it leaves 0 you're off the ground. You will also see the HUD VSI indicator rise to show that you're climbing. Check the Airspeed to see that you're still accelerating. If you are, hit the Landing Gear Switch to retract the undercarriage. Check the Gear Indicator, which should change from three green lights (gear locked down) to three reds (not locked down or up), and finally go out altogether (locked up).

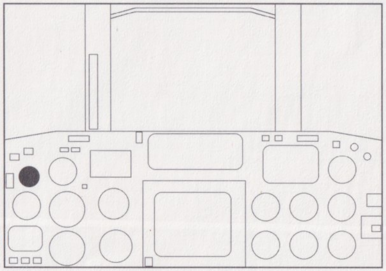
If you're not accelerating, you've got the nose too high - push it down a little - carefully!



Fuel Flow Indicator



Wheel Brake Indicator



Landing Gear Position Indicator

Step 5. Watch the HUD Airspeed Indicator. When you reach 215 knots, hit Flaps Up twice. You'll see the Flap Position Indicator rise from Mid-Flap to Manouevre Flap to No Flap. You're now cleaned up and ready to fly.

In short form, the drill goes like this:

Throttle OPEN, Reheat ON FULL
Wheelbrakes OFF (at 100% RPM and Max. Reheat)
Pull back (at 140+ knots)
Gear UP (at 10+ feet)
Flaps UP (at 215 knots)

After Take-off, you will normally (in the Tornado IDS) be levelling off quite low while you continue to accelerate to cruising speed - it should be quite safe to engage Track mode autopilot as you pass about 200'. Normal practice would be to cut Reheat as you pass 300 knots, and make the switch from 25 sweep to 45 sweep at about 350 knots. Operationally, your next task will usually be to turn on the AFDS in Track mode and watch the Time Early/Late indicator on the HUD, fine-tuning your speed with the autothrottle in order to arrive exactly on time at your first en-route waypoint.

Variations:

As we said above, the speed you need to rotate and lift off the runway will be strongly affected by the aircraft weight - a heavier aircraft will need a longer run, to reach a higher speed. You can try the effect of varying the aircraft weight by increasing or decreasing the fuel load and loading stores of various weights, using the Payload Window in the Mission Planner (see the Mission Planner chapter for details of how to do this).

ADVANCED FLYING TRAINING

CHAPTER 3

ADVANCED FLYING TRAINING

INTRODUCTION

This chapter assumes that you are reasonably confident that you know the functions of the major controls and instruments, you can fly the aircraft through simple manoeuvres, and you can take off and land with the assistance of the AFDS. We'll look more closely at the uses of flaps and slats as aids to tight manoeuvre and low-speed flying, leading up to a discussion of how to fly a loop and the many more useful variants of this trick. We then cover Terrain Following, the full range of navigation displays, Target-of-Opportunity waypoints, how to use AFDS Track mode and the Time Early/Late indicator.

Once you've been introduced to the full capabilities of the aircraft's navigation systems we go on to discuss how to set up for an approach and landing wherever and whenever you want, and then how to fly the approach for yourself without using AFDS Approach mode.

Finally we look at possible emergency situations and how to handle them, including Spin Recovery, the jettison options and Ejection. When you've covered all this material you'll understand the aircraft's capabilities far better, and you'll be ready to learn how to fight and survive.

MORE ABOUT FLAPS AND SLATS

As we said in Elementary Training, the primary use of flaps is to lower the stalling speed to allow the aircraft to fly as slowly as possible for approach and landing. Flaps are surfaces which slide out of the trailing edge of the wing and hinge downward. Slats are smaller surfaces which extend forward from the leading edge of the wing in a similar way. On the Tornado both flaps and slats extend and retract together in response to Flap Up and Flap Down commands, and both extend for almost the full span of the wing, which is unusual. It's only possible because the Tornado has no aileron control surfaces on the wings for roll control, which is provided instead by differential movement of the tail surfaces and by spoilers on the upper wing surface.

When flaps and slats are down they extend the chord of the wing (the distance from leading to trailing edge), increasing the wing area. They also deepen the camber of the wing, making it act like a wing which is thicker from top to bottom. There are other more subtle effects as well, but the end result of all of the changes is that the wing develops more lift for a given airspeed, and will tolerate higher angles of attack before it stalls, so the aircraft can safely fly more slowly.

As you might expect, there's bad news as well as good. The price for all the extra lift is extra drag, so it takes more thrust to fly at a given speed. When slowing down to land normally the drag is more useful than not, but if you're landing without power you won't be able to afford the loss of speed until the last moment. The other drawback is that the elaborate mechanisms add weight and bulk - especially so in a swing-wing aircraft like the Tornado. If the designer tried to specify flaps, linkages and actuators strong enough to operate over the entire speed range the resulting aircraft would be so heavy and draggy it would probably never leave the ground. So flaps and slats are only certified to operate below certain speeds - the limiting speeds. If you attempt to lower them or leave them down above these speeds, the best that you can hope for is that the mechanism will jam. The worst case occurs when the overstrained flaps

collapse on one wing but not the other, leaving an uncontrollable aircraft corkscrewing towards the ground.

Need I say more? DON'T exceed the flap limiting speeds! Here they are again:

Flap Limiting Speeds	
Manoeuvre Flap:	450 Knots IAS
Mid Flap:	280 Knots IAS
Full Flap:	225 Knots IAS

Because the Tornado has variable-sweep wings there is one more constraint on flap operation than you'll find in most aircraft. When the wings are at mid sweep, the full-flap setting is unavailable because the extending flaps would foul the fuselage side and the slot into which the wing trailing edge disappears. When the wings are at full sweep, no flap extension at all is possible: - the flaps are actually trapped inside the slot. Conversely, with mid flap selected you can't sweep back beyond mid sweep, and full sweep is unavailable if the flaps are in any position except fully up. There are automatic interlocks to prevent you from doing these things. One consequence of the interlock system is that you can't sweep the wings and change the flap setting at the same time; you must do one thing first and then the other. Here's a table of the possible combinations:

Flap / Sweep Compatibility

	25 Sweep	45 Sweep	67 Sweep
Zero Flap	Yes	Yes	Yes
Manoeuvre Flap	Yes	Yes	NO
Mid Flap	Yes	Yes	NO
Full Flap	Yes	NO	NO

Flaps and Manoeuvre

Manoeuvre Flap is the 'highest' flap setting, and as the name suggests it's intended to help you manoeuvre rather than land. This flap setting was chosen as an acceptable trade-off between the benefit of lift and the penalty of drag. If you're below the limiting speed for Manoeuvre Flap you can use it to turn more tightly than you can with the flaps fully up, and the extra drag is hardly worth worrying about. This boost to the aircraft's handling is mainly useful in air combat. The Tornado was not designed as a world-beating air-superiority fighter - it's not possible for any one aircraft to do everything well - and its strengths lie in other areas. As a result, most purpose- built fighters can out-turn it in many situations, though very few can roll faster. Using Manoeuvre Flap can help to narrow the gap in capability. See the Weapons Conversion chapter for detailed advice on Air Combat Manoeuvering (ACM).

As a simple exercise and demonstration of the use of flap for manoeuvre, go to the Simulator and call up the 'Free Flight (Airborne)' mission. Let's try flying loops: they're a useful starting point for many more useful types of manoeuvre.

Setting up for a Loop

The first essential for looping the aircraft is enough airspeed. Unlike the most powerful fighters, the Tornado cannot stand on its tail and accelerate straight up. You're going to lose speed on the way up, and you don't want to stall if you can avoid it. We would suggest that you start with an airspeed of about 450 knots IAS. If you have height to spare you can speed up your acceleration by means of a shallow dive, but beware...

The second essential condition is that you have enough height to recover if something goes wrong. For the moment let's set a lower limit of 5000 feet for starting the manoeuvre. As you gain experience and confidence you can bring this height down, but it'll be healthier for everyone if you do your experimenting in the Simulator.

The third condition is not strictly essential, but it's a good idea. Start the loop with the aircraft in a sensible configuration. Looping with the wings fully swept back is certainly possible, but only at high speed, and the diameter of your loop will be enormous. Mid sweep is probably the best all-round starting configuration. Above all, don't try this sort of manoeuvre with a heavily loaded aircraft until you know what you're doing - and preferably not even then.

Finally, turn off the Autothrottle. You'll see why in a minute.

Looping Step-by-Step

Read this drill first and then try it out: don't attempt to do both things at once!

1 Slam the throttles open to Combat power (Full reheat) and give the engine RPM and fuel flow a moment to catch up.

2 Pull the stick back all the way and hold it back. Be decisive about it. Though there's no need to punch yourself in the stomach, don't dither. The aircraft will pitch up and the airspeed will start to drop off. Watch the airspeed closely, and keep an eye on the pitch bars to monitor the progress of your loop. As you rise to the vertical the 90° bar will pass down across the HUD, then the pitch figures will start to fall again. The pitch bars will also help you to keep the wings level.

3 As soon as you're safely below the limiting speed (450 kts.), sweep the wings forward to the 25° setting; you'll see the pitch rate increase (the pitch bars will move faster down the HUD). When the indicator shows that the wings have stopped moving, hit Flaps Down once to select Manoeuvre Flap and you'll see the pitch rate increase

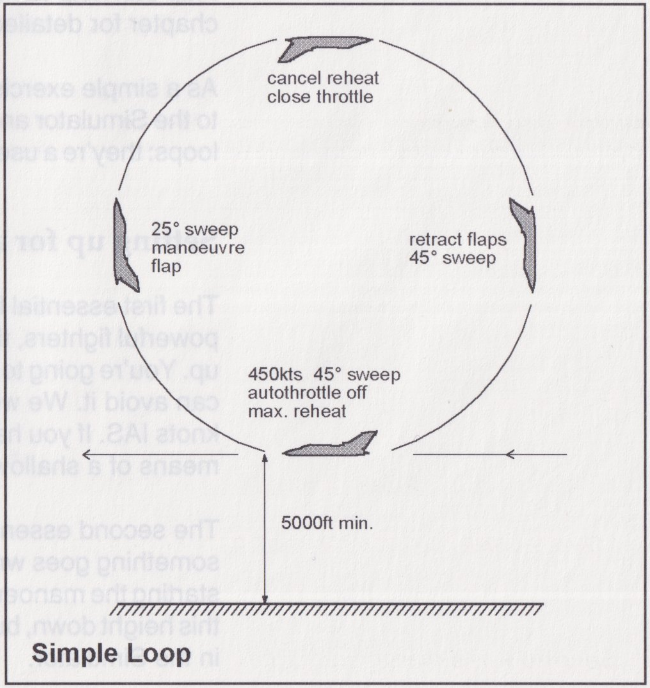


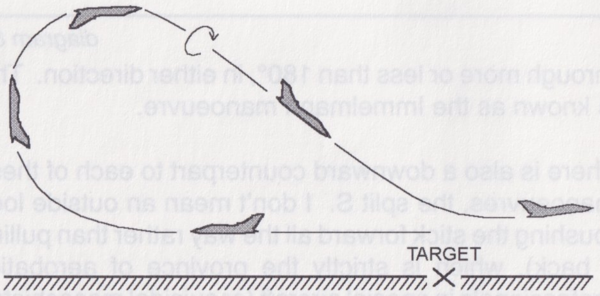
diagram 8.1

again. If your airspeed is worryingly low, you might want to drop the flaps further before you reach the top of the loop, though this shouldn't happen at moderate weight if you've followed the directions exactly.

4 At the top of the loop the aircraft is inverted. Keep pulling, though if your airspeed is dangerously low you might let the stick come forward a little way. Remember that the harder you pull, the bigger the drag.

5 As the nose passes the horizontal on the way down and the aircraft starts to accelerate again, cancel reheat and close the throttle (just Slam Shut twice). What we want is a loop, not a power dive. The aircraft will rapidly accelerate downhill under its own weight, and we're about to point the nose straight down at the ground. As the speed builds up again be sure to retract the flaps well below the limiting speeds, and be ready to go back to mid-sweep if necessary.

6 As the nose rises to the horizon again (the right way up this time) let the stick relax forward to level off. Note your altitude and speed and compare them with your starting values. And don't forget that you'll need to reopen the throttle!



Second Pass (Airshows Only)

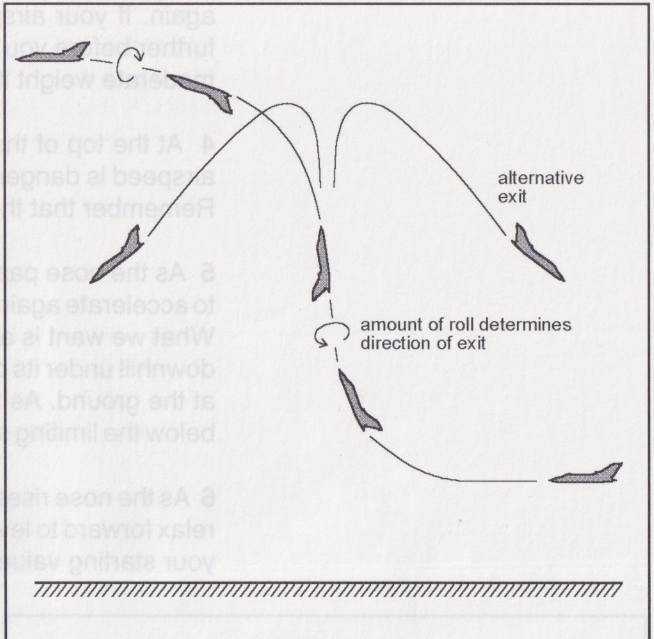
diagram 8.2

Beyond the Loop

Keep practising this manoeuvre till you can do it easily, and then try to find the limits. Try it at lower speeds, higher speeds, with and without Autothrottle. There are many variations on the basic manoeuvre, and most of them are more useful than a straight loop. If you roll the aircraft level at the top then you've reversed your course in the quickest way possible. Try making a low fast pass over some point on the ground, carrying on a short distance, then pulling back into a loop. Wait until the nose is pointing back at the target and then roll upright for another pass. Tactically this is a bad idea on two grounds: 1) making a second pass on a defended target is probably the cause of more combat aircraft losses than any other

single mistake, and 2) a single aircraft hurling itself vertically upward will attract SAMs and AAA from miles around. But it's good exercise and good fun, and the mental exercise involved in keeping track of which way it is to the target, whichever way up you are, is invaluable if you lack experience. If you start pulling up sooner rather than later after passing over your chosen target, you will also discover just how much height you need to pull out of a dive. Make sure that collision-detection is disabled (on the Mission Selection Screen) before you experiment, or you'll waste a lot of time crashing and re-starting.

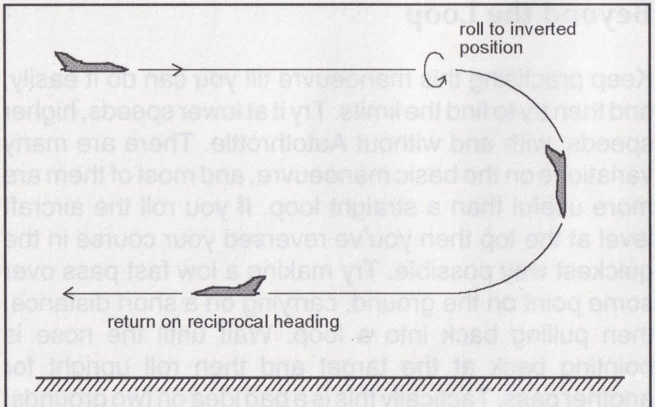
Try pulling up to the vertical, rolling 180°, then pulling back again and rolling level at the top. This will leave you more or less on your original heading, but several thousand feet higher. Obviously you could also roll through more or less than 180°, in either direction. This is known as the Immelmann manoeuvre.



Immelmann

diagram 8.3

There is also a downward counterpart to each of these manoeuvres, the split S. I don't mean an outside loop (pushing the stick forward all the way rather than pulling it back), which is strictly the province of aerobatics professionals in special aircraft (or suicidal masochists). What I'm talking about is rolling inverted from level flight and THEN pulling back. Obviously you need a fair amount of height before trying these variants. Find out how much.



Split S

diagram 8.4

You can string these various manoeuvres together in many different ways, for many different purposes, provided that you don't run out of airspeed or altitude. When you've tried all these things, one at a time and in combination, you'll have a far better grasp of what the aircraft can and can't do. Everything you can learn from these exercises will benefit you when it comes to Air Combat Manoeuvering.

TERRAIN FOLLOWING (IDS ONLY)

The aircraft's ability to fly automatically at low level over undulating terrain is probably the best-known feature of the Tornado IDS variant, though several other aircraft also have this ability. The original GR1 model does this by scanning the ground ahead with a radar to find the ridges it must climb above and the valleys it can dive into. In practice it's a very reliable system - it has to be, or the aircrew wouldn't trust it or use it.

Why Follow Terrain?

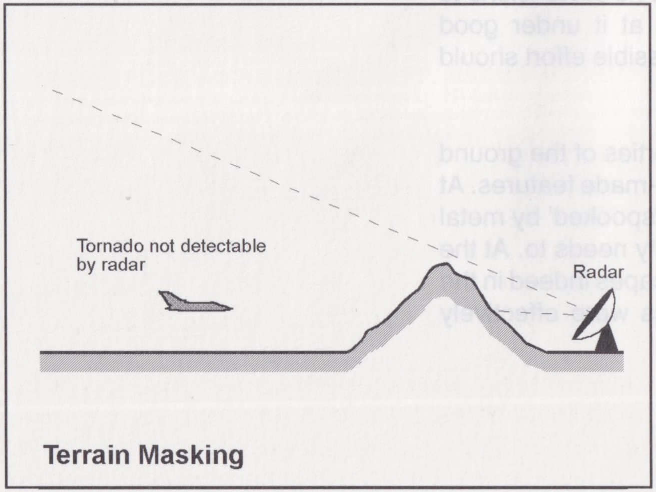


diagram 8.5

For as long as radar has existed, low-flying aircraft have been the hardest to detect. High ground between the radar and the aircraft will block the signal entirely. Even if there is a clear line of sight, a radar looking horizontally across the ground is half-blinded by echoes from the ground itself. A low-flying aircraft is also less visible to every other kind of sensor, from an infra-red system to the human eye. The later the aircraft is detected and the sooner it has passed out of sight, the shorter the time available for ground-based weapons to be aimed and fired. Anti-aircraft missiles, too, have a harder time tracking low-level targets, and may fly into the ground themselves. Even fighter pilots, who are not notoriously modest or timid people, will manoeuvre more cautiously when the ground is just a few aircraft-lengths away. With

when the ground is just a few aircraft-lengths away. With modern look-down fighter radars and snap-down missiles they can attack you from above, but you're still a difficult target. If you have to be a target then that's the best kind to be.

The Tornado's TF system gains you all these advantages, and lets you use them in conditions where most other aircraft would not even be flying, let alone flying at treetop-height. Night and low visiblity mean nothing to the TF system, provided that you trust it and know its limitations.

Disadvantages

The main problem with the GR1 Terrain Following Radar (TFR) is that it's an active system: like any radar it works by transmitting powerful radio signals and listening for the echoes (normally known as 'returns'). Though most of the TFR signal is directed at the ground the radar has to scan ahead of the aircraft, and an enemy with the right kind of receiver (like the Tornado's own Radar Warning Receiver) can pick it up from a distance. The Tornado has no pretensions to passive Stealthiness - if the enemy can point a radar at it under good conditions, he will definitely be able to see it - so every possible effort should be made to avoid drawing his attention.

Another (lesser) problem is that the radar-reflective properties of the ground vary considerably with soil type, vegetation cover and man-made features. At one end of the scale, this means that the system may be 'spooked' by metal structures on the ground into pulling up higher than it really needs to. At the other, some Tornado pilots in the Gulf had very narrow escapes indeed in the process of discovering that some enormous sand-dunes were effectively invisible to the radar!

TRN versus TFR

The solution proposed for the Tornado GR4 is based on digital mapping. For the last decade or more, cruise missiles have used stored digital relief maps to provide a cross-check on their navigation and to enable them to fly accurately at extremely low level. This is Terrain-Referenced Navigation - TRN. The guidance system uses radar briefly and discreetly to capture an image of the landscape, and then compares this with the stored maps to find its true position. To keep down the storage requirement (and hence the weight, bulk, complexity and cost), such missile guidance systems only store maps for a few critical portions of the route.

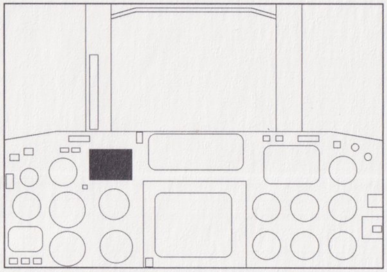
The cost, weight and bulk of computer memory have changed enormously for the better since then, the quality and quantity of digital map data have also been drastically improved, and the processing power now available can be used to analyse and present more data, more usefully, in less time.

The GR1's navigation systems combine automatic dead-reckoning and inertial navigation to keep track of the aircraft's position with a high degree of accuracy. But even so, the calculated position 'drifts' over time. It needs to be checked by the navigator at intervals, and brought back into line with reality. In the GR4 this realignment is performed by TRN, using only the data from the radar altimeter, which is designed to be as close to undetectable as a radar can be. A radar altimeter, which only transmits straight down, is inherently a lot stealthier than a Terrain-Following radar, which must look forward.

Because the GR4's navigation system holds a digital terrain map, and always knows precisely where the aircraft is, it can 'look ahead' on the digital map in order to follow the terrain.

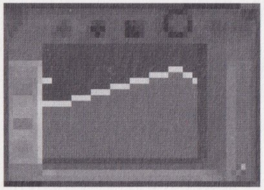
Terrain-Following with the AFDS - a demonstration

Select the Simulator, and call up the 'IDS - Free Flight (from Runway)' option. Select 'Take Off' in the Mission Planner, and once you're in the cockpit, get the aircraft off the ground. Fly straight ahead (a heading of 270), and once you've cleaned the aircraft up for cruising flight, engage the Autothrottle with a speed setting of about 420 knots. Now climb straight ahead to about 2000 feet. When you get there, hit the F9 key to put the AFDS into Terrain Follow (TF) mode. You'll see the mode change on the AFDS MFD display and the ALT status will change to 1500 RIDE (maintain a Ride Height of 1500 feet). If you look at the HUD altimeter, you'll see that a letter T has appeared below the digital altitude figure, which is prefixed by the letter R to show that this is a radar altitude (height above ground) rather than a barometric altitude (height above sea - or flat ground - level).



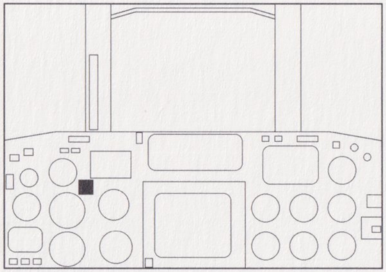
E-Scope

If you're over hills, you'll see that the aircraft is now pitching up and down under automatic control to maintain 1500 feet above ground, as closely as it can. If you're not above hills at the moment, look about to find some, and use left or right Control Stick movements to set the Heading Acquire figure to steer towards them, just as you would in Altitude/Heading Acquire mode. Moving the stick forwards or backwards will change the Ride Height figure, which can be set to 1500, 1000, 750, 500, 400, 300 or 200 feet. Set the Ride Height down to 200 feet by stages, pausing briefly each time to let the aircraft stabilise at the new Ride Height.



E-Scope

As you reach about 500 feet you'll notice that the E-Scope (the display above and to the left of the MFD) is starting to show an undulating green zone in its bottom section. As the Ride Height is reduced further, the green zone will rise up the display. The zone represents the profile of the ground directly ahead of the aircraft, shown relative to the fixed mark on the left-hand side of the display. As the aircraft moves, the ground profile shown in the E-Scope scrolls in on the right and out on the left. This is the data the TF system is using to decide whether it must climb to clear a ridge, or can dive to take advantage of a valley.


B-Risk Indicator

Now set the Autothrottle to a higher speed, say 550 knots, not forgetting to adjust wingsweep as necessary, and try to find some more hills. As the aircraft's speed increases, so the TF system needs to look further ahead for obstacles. The vertical scale of the E-Scope remains the same, but the horizontal scale changes to compress a greater distance into the fixed width of the display. What this means in effect is that the slopes start to look steeper. The faster you go, the more dramatic the effect becomes.

The TF system is smart and trustworthy, but it does have limits. The faster the aircraft flies, the more difficult it is to follow the ground closely, and the more dangerous it becomes to do so. The system allows itself a margin of error below the set Ride Height, and flashes the B-risk indicator (a red light below the E-Scope) when it exceeds that margin. If the B-risk indicator is flashing frequently, you should either slow down or increase the Ride Height if the situation allows. There is also an absolute limit below the safety margin. If the radar altitude falls this low, the system goes into panic reaction. It instantly rolls the wings level and pulls up hard away from the ground, then automatically disengages itself and sounds a warning to tell you.

The emergency pull-up is intended to save you if possible, but it may not be triggered until it's too late. It is not guaranteed to save your life. If you want to try it out, find a long stretch of level ground free from tall obstructions and very carefully fly the aircraft by hand down to 100 feet or less. When you've done this, engage TF mode and the system should trigger an emergency pull-up immediately. As you engaged it, the TF system automatically selected the nearest Ride Height (200 feet) and found that it was below the absolute safety limit.

Quite apart from the fact that it can't be guaranteed to prevent you from flying into a steep hillside at high speed, there is another excellent reason to avoid relying on the emergency pull-up. The reason you're Terrain-Following in the first place is to avoid drawing the enemy's attention, and a Tornado rocketing upwards like a scared pheasant is bound to attract it!

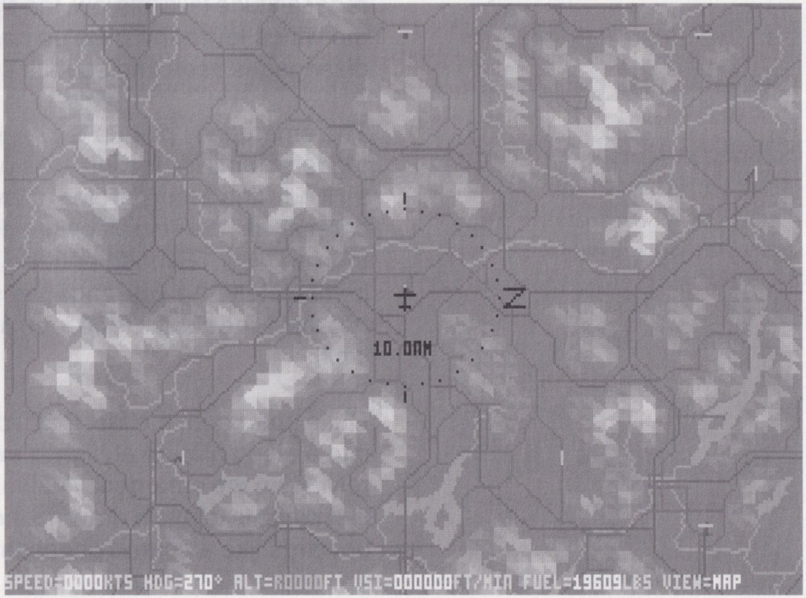
MAPS, THE MFD AND THE TAB DISPLAYS

Because the navigation displays and systems are powerful, comprehensive and quite complex, there's a lot of material to cover, so you'll probably want to use Pause frequently, or even restart the whole exercise at intervals. As an incentive to wade through this stuff; when you've absorbed it you'll be able to tell the aircraft to fly itself to any point on the map by simply pointing with the mouse and clicking! To get things started, select Simulator, and the 'Free Flight - Airborne' mission, and commit. Engage the AFDS in Altitude/Heading Acquire mode, so that you hold your current heading of 270° (due West).

Full-Screen Moving Map

To call up the Full-Screen Moving Map hit the M key (check with the Control Summary). As the name suggests, this uses the entire screen area to display a map. The map scrolls automatically to keep the aircraft in the centre, shown as a symbol surrounded by a compass rose with North marked. The map also rotates as the aircraft turns, so that the direction of flight is always straight up the screen.

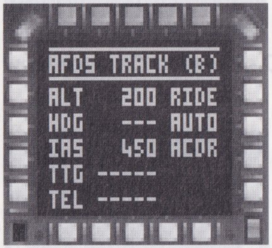
Because of the large size, this map covers a larger area and offers better resolution than any of the other map displays available in the cockpit. You can also zoom in and out - check the Control Summary to find out how to do it. To go from this display to any other view, just hit the key for the view you want.



Moving Map

Multi-Function Display (MFD) Modes

Shift to the front cockpit view. By repeatedly hitting the MFD Function Select key (probably D) you can cycle through a variety of displays. The full list of possible MFD displays is as follows:



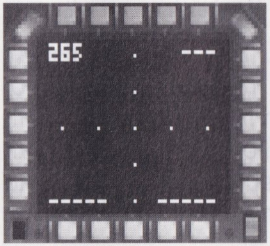
MFD - AFDS Display

1. AFDS/Autothrottle Status Display

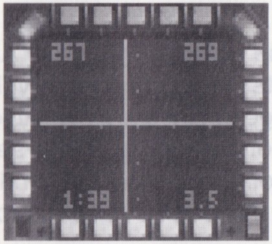
You've already seen this display. It will be available whenever AFDS or Autothrottle are engaged. Engaging either will automatically select this MFD display, though you can still select any other available display using MFD Function Select.

2. ILS Display

This display is available at any time, but it will only become active when you are inside the ILS coverage of an allied airfield and pointing in the general direction of the runway. For details, see the section on Semi-automatic and Manual landings later in this chapter.



MFD - ILS (not active)



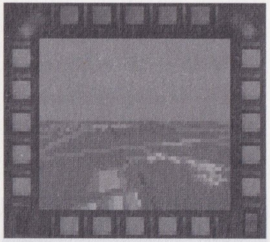
MFD - ILS (active)

3. Local Map Display

Available at all times, and covered in detail below. Users of slower computers may want to use this display only from the back cockpit since it requires heavy processing and may have a visible effect on the frame update rate. The impact is much less when the map is zoomed in to show smaller areas.

4. Forward-Looking Camera

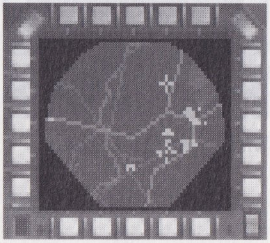
Available on the back-seat MFD at all times, but only at night on the Front Panel. Displays a normal full-colour image in daytime, and an image-intensified view at night. When used in the front cockpit it may visibly slow the frame update rate.



MFD - Forward Camera View

5. Ground Radar Display (IDS only)

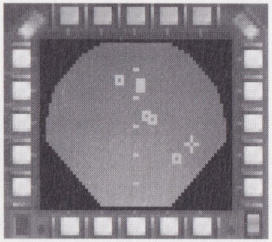
Available only when the radar is on, and in Ground mode. This is a synthetic composite display combining digital map data and radar returns. Returns from objects not found in the map database are shown as bright dots - this is a good way of locating vehicles or trains. Ground Radar can be used to designate targets of opportunity, and is covered in detail in the Weapons Conversion chapter. This is another power-hungry display, but like the Local Map Display it is less demanding when the range setting is short, and of course it can be used from the back cockpit without visible impact on the frame rate.



MFD - Ground Radar Display

6. Air Radar Display

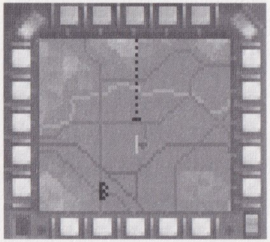
Available only when the radar is on, and in Air mode. This is a plan display showing aircraft detected in a fan-shaped volume in front of your Tornado. Short and medium-range settings are available in both IDS and ADV aircraft, but only the ADV radar offers the long-range setting. Allied and Enemy aircraft are distinguished by different symbols, and the display can be used to designate targets in air combat. Air Radar is covered in detail in the Weapons Conversion chapter.



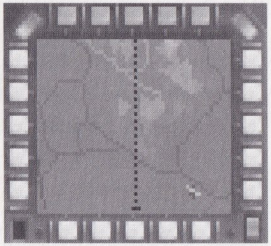
MFD - Air Radar Display

7. Display Unavailable/MFD damaged

If a particular display is not available because of equipment failure, you may see a green diagonal cross substituted for the normal display. The MFD itself may also suffer damage, in which case the display will degenerate into noise. If you find this annoying, you can turn the MFD off altogether.



Local Map Display, centre origin

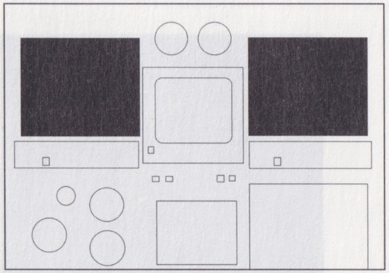


Local Map Display, base origin

The Local Map Display in detail

Use the MFD Function Select key to bring up the Local Map Display. Like the Full-screen Moving Map, this display rotates as the aircraft turns so that the aircraft always points straight up the screen - as shown by the vertical line of dots projecting the current heading. Also like the Full-Screen Moving Map, this map scrolls to keep your current position in the same place on the screen, but you have two Map Origin Modes giving some choice as to where the display will be centred.

When you first see this display it will show the aircraft's position at the centre of the screen, with the dotted line extending from there to the top. This is the Centre Origin mode, which lets you see the area behind as well as in front of the aircraft. Hitting the Map Origin Select key (probably O), will switch to Base Origin mode, which puts the aircraft position at the bottom of the display in the centre. The dotted line now extends from top to bottom of the display. Base Origin mode allows you to see further ahead of the aircraft. Hitting the Map Origin Select Key will always switch from one mode to the other. The map can be zoomed in or out in either of these modes (see the Control Summary under Local Map Zoom).



TV TAB Displays

Into the Back Cockpit: TV Tab Displays

Because of the restricted size of the MFD, the Local Map is intended for short-range orientation and navigation only. For serious work we need to shift to the back cockpit, where the Navigator/Weapon System Officer works. Here there are three displays side by side. The centre display is an MFD just like the one on the Front Panel, with all the same display modes available plus a daytime forward camera view. The larger displays on either side are known as the Tab displays. This peculiar name is short for TV Tabulator (a relic of early computer equipment nomenclature), but they are simply a larger form of multi-function display.

Look up Left Tab Function Select and Right Tab Function Select (probably the [and] keys), which are used to cycle each screen through its range of displays. Some of these are unique to the Tab displays, and some are shared with the central MFD. To save you time in cycling through the options for any of the three displays, you will only be offered display modes which are not already shown on another screen, e.g. if you select the Local Map on the right Tab display, you will find that the MFD will not offer this display if you cycle through its options. Similarly, you can never have the same display on both Tabs at the same time. Use the MFD Function Select key to bring up the AFDS display, which is not available on the Tab screens (remember that you won't see this unless the AFDS or the Autothrottle are engaged). This will ensure that the full range of Tab displays are available for you to see.

In the bottom left corner of each of the three displays is a green light which only ever illuminates on one display at a time. This light is used to show which display currently has use of the mouse as an input device, and pressing the Select Active Display key (probably Tab) will switch the mouse from one display to the next in a continuous cycle. For the moment, make sure that the right Tab's green light is on.

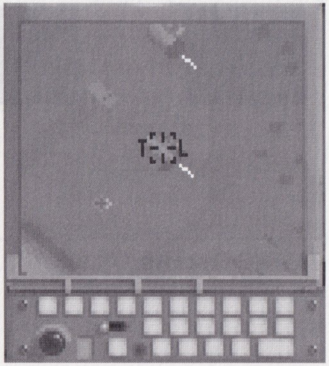
Now use the Right Tab Function Select key to cycle through the available displays. Between the modes available on the right Tab screen, and the one displayed on the Left Tab screen, you should find all of the following:

1. Forward Looking Camera

Exactly like the corresponding MFD display, but larger and more useful.

2. TIALD Image

TIALD stands for Thermal Imaging And Laser Designation, and this mode is unique to the Tab displays. This is the view from a steerable downward looking camera system on the underside of the aircraft. It is not available when the aircraft is on the ground, because the lenses must be protected from debris thrown up by the landing gear. It is also unavailable when roll or pitch attitudes are extreme. When the view is not available a large diagonal cross fills the display.



TIALD Image

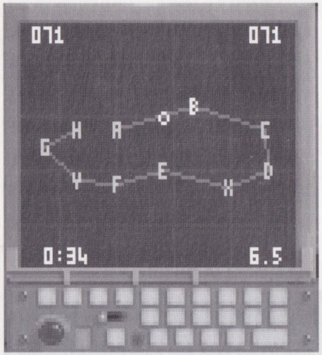
The TIALD system is mainly used from medium altitude to designate targets for Laser-Guided bombs, and it is described in detail in the Weapons Conversion chapter.

3. Local Map Display
This works exactly like the MFD Local Map Display, but is larger and more useful. It is not available if the back-seat MFD is already displaying the Local Map.

4. Scrollable Map
This mode is only available on the Tab displays. You can distinguish it from the Local Map because it doesn't have a dotted line down the centre. It is described in detail below.

5. PLN (Flightplan) Display
This mode is only available on the Tab displays. It shows a schematic of the flightplan currently stored in the aircraft's navigation system, the location of any target-of-opportunity waypoint, and the aircraft's position relative to these. Zoom level and display origin will change automatically to keep all of these elements on the screen, provided that you don't fly off the map.

The PLN display is described in detail below, in the section covering AFDS Track mode.



PLN Display

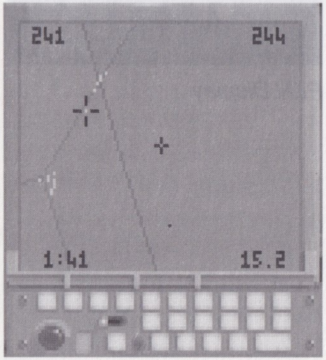
The Scrollable Map Display in detail

This is your most powerful navigational aid. Like the Local Map, this map display rotates as the aircraft heading changes, so that the aircraft's direction of movement is always straight up the screen. Unlike the Local Map, however, this display does not scroll automatically to keep your current position at a fixed point on the screen. Check that the right Tab's green Mouse Active light is on, and try moving the mouse about. You will see that moving the mouse scrolls the map freely in all four directions, out to the limits of the Training Area. You can also zoom in and out by clicking the left and right mouse buttons while holding down the [Control] key.

There is a numerical readout in each corner of the display, and working clockwise from top left these are: current aircraft heading, bearing to the map position centred on the screen (marked by the small fixed cross), range in nautical miles to that position and time in minutes and seconds required to get there at current speed (provided that the aircraft is pointing in that general direction).

If you scroll away over the map and lose track of your current position you can find the aircraft quickly by clicking the left mouse button while holding down the [Alt] key. This centres the display at your current position where you will see a small aircraft symbol. Wait a few seconds and you will see the symbol move up the screen as it tracks your position.

These features make the Scrollable Map the most useful of all. However, its most powerful feature is the ability to set a Target-of-Opportunity waypoint.



Scrollable Map

Setting a Target-of-Opportunity Waypoint

Use the [Alt] and left click combination to find your aircraft again, scroll the map some way ahead of your current position, and find an identifiable feature. For example, this might be an airfield, a city, a village or a bridge. Now click the left mouse button on its own. This will create a Target-of-Opportunity waypoint at

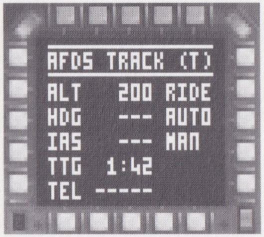
that location. If you scroll the map a little away from the point you selected, you'll see that it is marked by a flashing cross. If you click the RIGHT mouse button while holding down the Alt key, the map will centre itself on the waypoint again. Clicking the RIGHT mouse button on its own cancels the waypoint.

A waypoint is just a map position stored by the aircraft navigation systems. It may be the position of a target, more often it's a place where you want to make a course change. Waypoints which are part of the stored flightplan are labelled in alphabetical order from A to O, with the letters X, Y and Z used for planned targets - you can see the stored flightplan on the Tab PLN display (call it up on the other Tab display if it isn't there already). These waypoints can only be set up in the Mission Planner. The waypoint you've just placed is different; it's called the Target-of-Opportunity waypoint, it's shown on the PLN display by the letter T, and obviously you CAN set this one in flight, at any position you like (provided that it's within the current map area).

Target-of-Opportunity (ToO) waypoints can be used exactly as the name implies - to make accurate attacks on unplanned targets with the aid of the navigation systems. You can also create ToO waypoints using the Ground Radar display on the MFD. We'll deal with how to make attacks of all kinds in the Weapons Conversion chapter, but here we'll talk about using the ToO waypoint for navigation.

AFDS Track Mode

So far we've used the AFDS in Altitude/Heading Acquire, Terrain Follow and Approach modes. Track mode is the 'smartest' mode of all, and the one you'll use most often operationally. In Track mode the aircraft will automatically follow the stored flightplan, flying itself from waypoint to waypoint, performing attacks (in most delivery modes), adjusting height to terrain follow or hold altitude as laid down in the flightplan. In the absence of interruptions from the enemy, the AFDS in Track mode is quite capable of flying an entire strike mission for itself from just after take-off to just before touchdown.



AFDS Track Mode

Human intervention is only required for takeoff, setting autothrottle and wing sweep, arming and committing weapon release, pulling up if it's a loft delivery, landing and bringing the aircraft to a halt. Later on, we'll look at the normal use of Track mode to follow a complete flightplan. What we're going to do now is use Track mode to fly the aircraft automatically to the Target-of-Opportunity waypoint, T.

One of the waypoints shown on the Tab PLN display is highlighted. This is the currently selected waypoint, and if you engage AFDS Track mode the aircraft will automatically fly towards this waypoint. Flightplan waypoints are normally selected in automatic sequence, though you can override this by hitting the Skip Waypoint key. The only way to select T as the current waypoint is to hit the T key. Do this now, and check to see that the T on the Track display is highlighted. Now engage AFDS Track mode (F7), and watch the aircraft turn and fly towards T. This is literally point-and-click navigation, a boon for the lazy, the confused or the preoccupied!

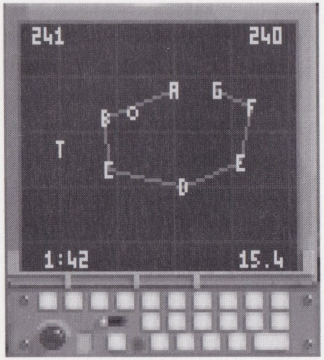
If you've followed the directions in this tutorial faithfully, you were in Altitude/ Heading Acquire (AHA) mode before you switched to Track mode, and you'll see that the hold altitude carries over despite the switch of mode. While the AFDS is in Track mode, hitting the TF Engage key (F9) will toggle altitude control between AHA mode and Terrain Following, (provided that you're flying an IDS Tornado - the ADV can't Terrain Follow) and in either mode you may change the height setting in the normal way by moving the Control Stick backwards or forwards. Be careful when switching from Terrain Following to Altitude Hold or you may find yourself flying into a hill! You cannot change the heading manually in Track mode, because this is automatically defined by the bearing of the selected waypoint.

In Track mode the AFDS MFD display shows several new items. One of these is the letter identifying the currently-selected waypoint - the one which the system is steering towards. At the moment it should show T. When Track mode is engaged there will always be a TTG (Time To Go) legend on the display, though a figure will not always be shown beside it. This shows the time in minutes and seconds before you reach the selected waypoint at your current

speed. It is only displayed when the aircraft is pointing in the general direction of the selected waypoint; if it's pointed away (e.g. when there's a large angle to turn through) it's difficult to calculate a meaningful Time-To-Go figure.

You should notice an arrow-shaped symbol beneath the heading strip on the HUD - this also shows the bearing to T, the currently-selected waypoint (or any other waypoint which is selected). When the bearing symbol is lined up with the vertical 'lubber line' you're pointing straight at the waypoint, allowing you to follow a flightplan manually as well as automatically.

The Tab PLN Display



TAB PLN Display

We've already introduced you to most of the uses of this display in the sections above, but let's sum up the details now and complete the description. The PLN display shows all waypoints and the stored flightplan, plus your current position (as a small circle). It will change scale and re-centre itself automatically to keep all this data on the screen as the aircraft moves or ToO waypoints are created; but if the aircraft moves too far outside the current map it will give up the attempt to keep it on-screen. The PLN display does not rotate, and is always oriented North-up, like the map in the Mission Planner which is used to create flightplans.

The currently-selected waypoint is shown highlighted, and is normally one of the stored flightplan waypoints. If you create a ToO waypoint using the Scrollable Map, you can select and highlight it by hitting the [T] key. To deselect the ToO waypoint, use the key combination [Control]+[T], which will also reselect the previously selected flightplan waypoint.

As on the Scrollable Map, figures are shown in the four corners of the PLN display. Clockwise from top left these are: current aircraft heading, bearing of the selected waypoint, range (in nautical miles) to the selected waypoint and (when appropriate) time to reach it at current speed.

Using AFDS Track Mode with stored flightplans

This is the normal use of Track mode. Whether it's supplied ready-made for a Single Mission, or hand-crafted by yourself using the Mission Planner software, the stored flightplan consists of a sequence of waypoints and the legs connecting them. Flightplan waypoints may also have other information associated with them. This may specify the altitude or Ride Height to fly at, the time at which you plan to pass the waypoint, or the method you intend to use to attack a target located there. We describe the system in exhaustive detail in the chapter of this manual dedicated to the Mission Planner. All we're going to do now is demonstrate how to use the AFDS to follow the flightplan.

From the Simulator Mission Selection Screen, select the 'Nav. Exercise' option and commit. This will take you to the Mission Planner, where you should be able to see a preset flightplan on the map. When you know how to use the Mission Planner you'll be able to change this to suit yourself, but for the moment just click on the button marked Take Off, which is on the right-hand side of the screen.

When you arrive in the cockpit, take off and climb straight ahead to an altitude of at least 200 feet, not forgetting to raise gear and flaps. When you reach 200 feet, hit F7 to engage Track Mode. Let the aircraft accelerate to about 420 knots, then cut in the Autothrottle and go to 45 sweep, the normal cruise configuration. On the MFD AFDS display you should be able to see all the data we've explained above, and one more line will have become active, titled TEL.

TEL (Time Early/Late) Displays

If you're taking part in a multi-aircraft attack, then every aircraft's time of arrival and attack should be planned to the second in order to cause maximum confusion and embarassment to the target defences - and to minimise the chances of one aircraft being damaged by the blast of another's weapons. On the way to and from the target, Tornado IDS will normally fly in widely-spaced tactical formations, and it's impossible to hold your place in the formation by

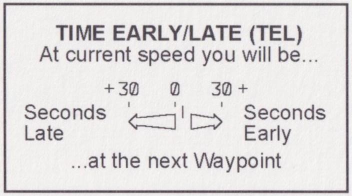


diagram 8.6

eye. Absolutely precise timekeeping is a necessity if the mission flightplan is to stand any chance at all of surviving contact with reality.

When the mission flightplan is created, most of the waypoints are tagged with planned times-of-arrival. When the aircraft is flying towards a selected waypoint which has a set time-of-arrival, the navigation systems continuously calculate a predicted time-of-arrival on the basis of your current position and speed. The difference in seconds between the planned and predicted figures is shown as the Time Early/Late. The TEL line on the AFDS display is self-explanatory, but the TEL display on the HUD needs description, though it's simple once you know how it works.

When the TEL HUD display is active, it appears as a short vertical line and three horizontally-spaced dots just below the HUD Airpeed indicator. The vertical line moves sideways between the centre position and the outside dots, left for late and right for early. If you're right on time, the line is below the centre dot; if it's at the left dot you're 30 seconds late or more; at the right dot you're early by 30 seconds or more. Smaller deflections left or right indicate smaller deviations from the schedule.

While the TEL displays make really accurate timekeeping much easier, you'll find it difficult to achieve this in practice unless you have some idea of what speed the mission plan required over each leg of the flightplan. This subject is treated in much more detail in the Mission Planner chapter, but in general you won't go far wrong if you assume that the flightplan expects a cruising speed of 420 knots, rising to 500-600 knots for attack and egress runs.

The drill for adjusting your speed to stay on schedule might go something like this:

1 Adjust Autothrottle setting for the nominal speed over the current leg of the flightplan.

2 Wait for the aircraft speed to adjust to the new setting and watch the TEL indicator. If you're late, adjust the speed upward, if early, reduce it. Remember

that the adjustment won't affect the TEL calculation until the actual aircraft speed has changed.

3 Keep an eye on the TTG figure as well, if possible. The further you are from the waypoint, the less accurate the TEL figure is. Unless you're on an attack run, don't bother to adjust small discrepancies until the TTG figure shows less than a minute to go to the waypoint.

When the aircraft reaches the currently selected waypoint while in AFDS Track mode, the next waypoint in the flightplan is automatically selected and the aircraft turns towards it. If it's a target, you'll need to hit 'arm air-to-ground weapons'. The AFDS can fly most planned attacks for itself, though you'll need to fly loft profiles manually, and weapons cannot be released unless you hold down the Commit button. See the Weapons Conversion chapter for more details. If the aircraft reaches an Approach Point within an allied ILS beam while under Track mode control, the AFDS will automatically switch to Approach mode for landing. If you want to fly parts of the flightplan manually, you'll have to advance the selected waypoint yourself at the end of each leg, using the Skip Waypoint command (see below).

When you reach a waypoint and the aircraft turns onto the next leg, the TEL displays will not be active until the nose is pointing in the general direction of the next waypoint. Don't adjust your speed during the turn if you can avoid it. There are two good reasons for this: a) you can't see the indicator, and b) the mission flightplan assumes that even if the planned speeds for the two legs are different, you won't change your speed until you've finished the turn.

It will take some time and practice before you become proficient at keeping to your timetable, which is why this 'Nav. Exercise' mission exists. Once you are familiar with the Mission Planner you can construct your own exercises if you wish, starting either from here or from the 'Free Flight (from runway)' option. Until you can fly accurately to schedule, you're nothing but a menace on a multi-aircraft mission.

Having said all this, it's a foregone conclusion that things will still go wrong for you, as long as the enemy refuses to cooperate. So what then?

Desperate Measures: Skipping Waypoints

Suppose that you're flying an operational mission, you're on track and on schedule, and then suddenly your Radar Warning Receiver tells you that there's an unexpected AAA unit ahead, or an interceptor coming your way? Either you abandon the mission or you try to find a way to dodge the hazard. If you decide to press on you're going to have to manoeuvre or change your speed or both, and that will definitely interfere with the timetable. Assuming that you do evade the threat, there's only so much you can do in the way of speeding up or slowing down before you run into problems with stalling speeds, limiting speeds or fuel constraints.

One of the options open to you is to cut a corner. This might run you straight into a new hazard, but it could be your only chance to make the target on time. This is why the Skip Waypoint command exists. It's very simple to use; just move to the back seat, call up the PLN display if it's not already visible, and hit the Skip Waypoint key (probably N) to advance the currently selected waypoint to the next in sequence. You can use this command from the front seat if you wish, but it's easier to see what's going on if you watch the PLN display.

You can repeat the comand as many times as you like, and cycle all the way through the list again if you overshoot, but if you leave the AFDS in Track mode while you do it, be aware that the aircraft is going to twitch all over the place in response to the flurry of rapidly changing steering demands. Even more significantly, the altitude authority mode and height setting may change from waypoint to waypoint, possibly running you into a hill. To avoid this problem, disengage the AFDS and either fly the aircraft manually or re-engage in plain TF mode until you've selected the right waypoint.

SETTING UP YOUR OWN APPROACH AND LANDING

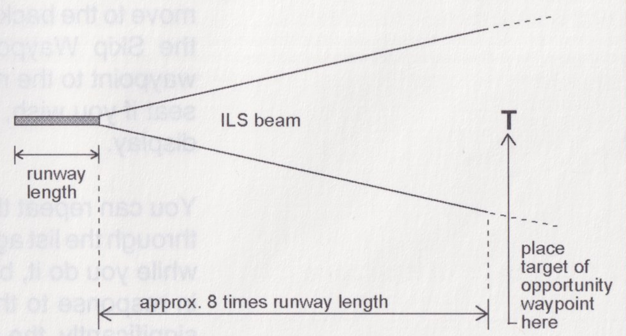
If you're following a properly made flightplan and nothing goes wrong en route, you can arrive at the Approach Point under AFDS Track mode control flying in the right direction to make a straight-in approach. There will be times, though, when you'll need to approach from another direction, or land at another airfield altogether. Let's look at how to do this for yourself; now that you've been introduced to the map displays, the Target-of-Opportunity waypoint, and AFDS Track mode it's not too hard to do, or to explain.

The problem breaks down into two main sections: 1) Finding a runway to land on, and 2) Setting up to approach it from a sensible direction and distance, so that you can use the Instrument Landing System (ILS) and AFDS Approach mode if you wish. If you want to follow this exercise through in the Simulator, select a 'Free Flight (start airborne)' mission, but don't try to set up to land on the airfield beneath your starting position without first flying a good way away from it.

Finding a runway, placing an Approach Point

Finding a runway isn't difficult if you use the map displays. The Full-screen map, zoomed well out, is probably the best one to start with. Use this to find an airfield which is neither too close, nor too far away, and remember roughly which way it is from your current position (remember, the map rotates so that your aircraft is always flying straight up the screen).

Now switch to the back cockpit and call up the Scrollable map on one of the Tab displays. Use [Alt]+left click to centre on your current position, zoom right out and scroll

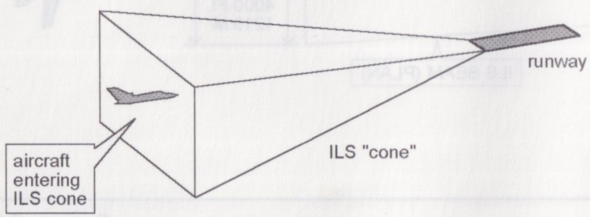


Home-Made Approach Point in Relation to Airfield

diagram 8.7

the map in the right direction to find your target airfield. Refer back to the Full-screen map if necessary to find your way. When you bring the airfield on-screen you will be able to see that the active runway (the one you want to use) is shown in a contrasting colour.

If there's a significant wind blowing, landing in one direction will be vastly preferable to landing the other way, but we'll leave this subject for later. With the airfield on screen and the Scrollable Map zoomed right out, click the left mouse button to place waypoint T about 7 or 8 runway-lengths from the airfield, IN LINE WITH THE RUNWAY. You now have a home-made approach point. Hit [T] to make waypoint T the currently-selected waypoint, and you can engage Track mode to fly you there.



Schematic of ILS 'cone'

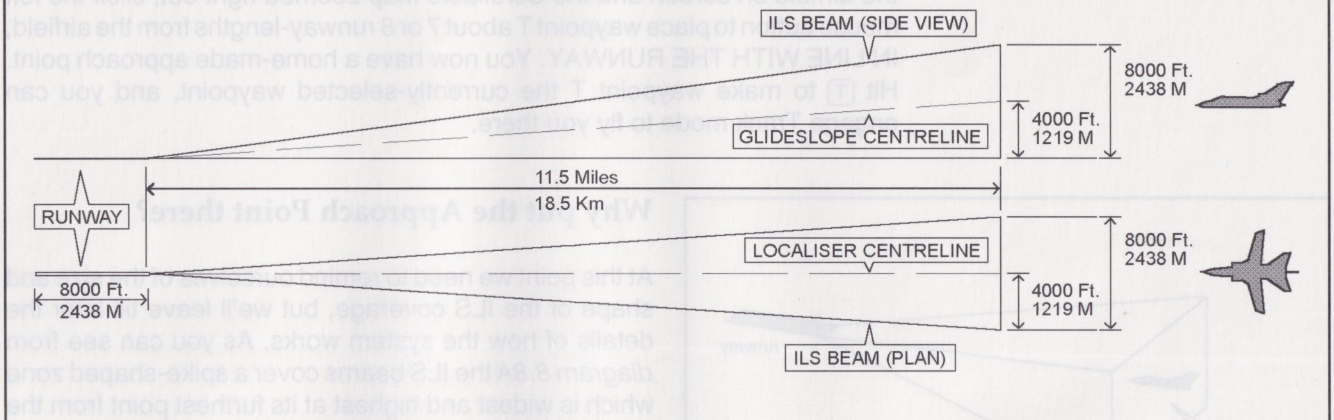
diagram 8.8A

Why put the Approach Point there?

At this point we need to remind ourselves of the size and shape of the ILS coverage, but we'll leave till later the details of how the system works. As you can see from *diagram 8.8A* the ILS beams cover a spike-shaped zone which is widest and highest at its furthest point from the runway. This is about 60000 feet (10 nautical miles or 18 kilometres) from the runway threshold. Since all the active runways you'll find in Tornado are about 8000 feet long, this means that the big end of the wedge is almost exactly 8 runway-lengths from the middle of the runway. That's why we advised you to place waypoint T at that distance from the runway end. You'll have to enter the ILS zone and point the aircraft in roughly the right direction before the ILS displays will activate and AFDS Approach mode can be engaged.

You can see from *diagram 8.8B* that the beam is 8000 feet high at extreme range, and the AFDS will find it easiest to line up for the approach if you enter the beam near the centre, so set the AFDS for Altitude hold (still under Track

mode) at about 4000 feet. The next question, and the most important, concerns how you're going to line up for the approach when you reach waypoint T. This depends entirely upon the angle between the line of the runway (call it the centreline), and the line along which you're approaching waypoint T.



Instrument Landing System Coverage

diagram 8.8B

How to line up for your Approach

Diagrams 8.9A,B and C illustrate a number of situations and possible ways of dealing with them. You can find out which diagram most closely resembles your real-life situation by looking at the scrollable map display. Because this display rotates to keep your aircraft pointing up the screen, you should be able to tell at a glance what sort of angle you'll need to turn through in order to line up.

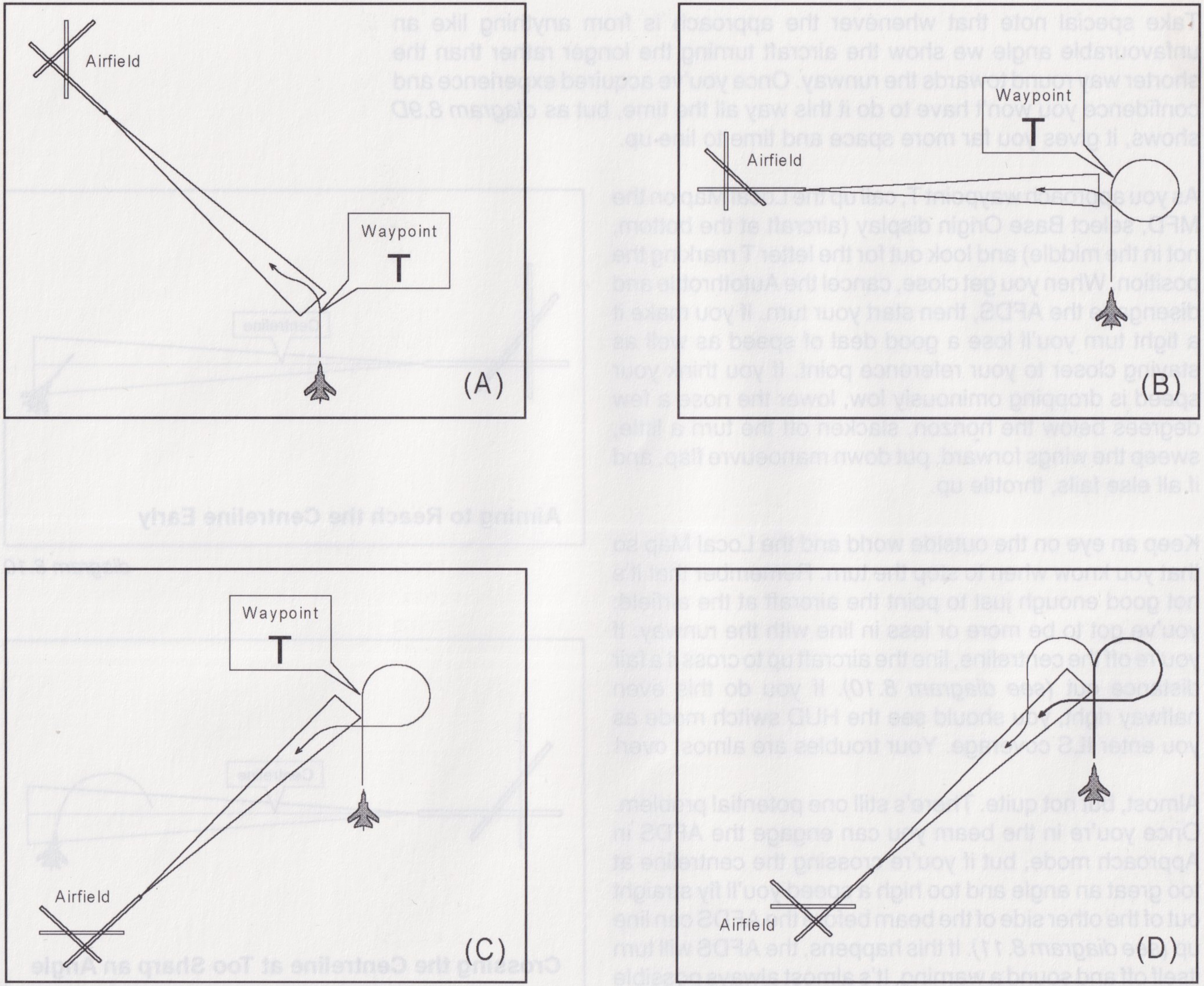
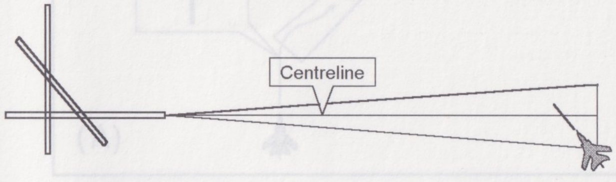


diagram 8.9A,B,C and D

Take special note that whenever the approach is from anything like an unfavourable angle we show the aircraft turning the longer rather than the shorter way round towards the runway. Once you've acquired experience and confidence you won't have to do it this way all the time, but as *diagram 8.9D* shows, it gives you far more space and time to line up.

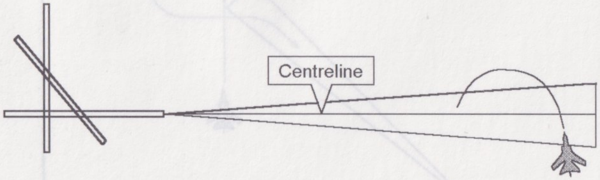
As you approach waypoint T, call up the Local Map on the MFD, select Base Origin display (aircraft at the bottom, not in the middle) and look out for the letter T marking the position. When you get close, cancel the Autothrottle and disengage the AFDS, then start your turn. If you make it a tight turn you'll lose a good deal of speed as well as staying closer to your reference point. If you think your speed is dropping ominously low, lower the nose a few degrees below the horizon, slacken off the turn a little, sweep the wings forward, put down manoeuvre flap, and if all else fails, throttle up.



Aiming to Reach the Centreline Early

diagram 8.10

Keep an eye on the outside world and the Local Map so that you know when to stop the turn. Remember that it's not good enough just to point the aircraft at the airfield; you've got to be more or less in line with the runway. If you're off the centreline, line the aircraft up to cross it a fair distance out *(see diagram 8.10)*. If you do this even halfway right, you should see the HUD switch mode as you enter ILS coverage. Your troubles are almost over!



Crossing the Centreline at Too Sharp an Angle

diagram 8.11

Almost, but not quite. There's still one potential problem. Once you're in the beam you can engage the AFDS in Approach mode, but if you're crossing the centreline at too great an angle and too high a speed you'll fly straight out of the other side of the beam before the AFDS can line up *(see diagram 8.11)*. If this happens, the AFDS will turn itself off and sound a warning. It's almost always possible to haul the aircraft back into the beam and recover the

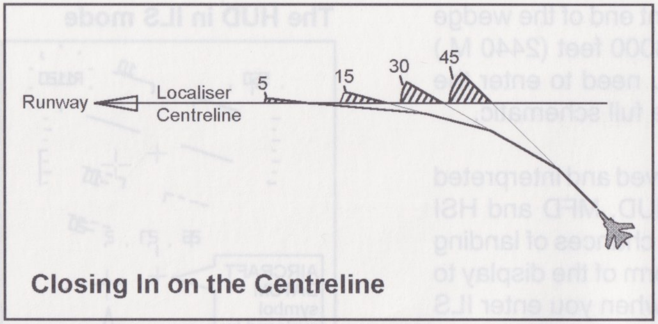


diagram 8.12

situation, but it's better to avoid the problem altogether. This is one reason why it's a good idea to enter the beam at a fairly low speed say no more than 350 knots. The other and more significant way to avoid the problem is to ensure that the closer you get to the centreline, the smaller the angle at which you'll cross it. This is illustrated in *diagram 8.12*, and is effectively what you'll be doing all the way down the approach once you learn to fly it manually, which is what we'll be looking at next.

SEMI-AUTOMATIC AND MANUAL LANDINGS

AFDS Approach mode control is a neat and useful aid, but any self-respecting pilot should be able to fly the entire approach and land by hand with a minimum of automatic help - or (s)he will have no choice but to eject if the AFDS fails or the airfield ILS system is bombed out. The sophistication of the Tornado systems means that there is an easy intermediate stage between a fully automatic and a fully manual landing.

Semi-automatic Approach:- ILS and Autothrottle

In this type of approach we'll use the ILS (Instrument Landing System) as a manual steering cue, and leave speed management to the Autothrottle. First let's look at the ILS system in detail. Your aircraft's ILS displays are driven by transmitters and aerials on the ground, pointing up the approach path. There are effectively two fan-shaped radio beams; one (the Localiser) to tell you whether you are to the left or to the right of the runway centreline, and the other (the Glideslope) to tell you whether you are above or below a steady 3° slope which meets the ground at the runway threshold. The coverage of these two beams defines a square wedge with one side resting on the ground and the point at the runway threshold. To avoid your being misled by weak and possibly

distorted signals, there is a sharp range cut-off, so the blunt end of the wedge is flat. This end defines a square 'hoop' in the sky with 8000 feet (2440 M.) sides. To exploit the maximum range of the system, you need to enter the beam by flying through this hoop. See *diagram 8.8A* for a full schematic.

In the aircraft, the localiser and glideslope beams are received and interpreted to drive ILS displays, which are provided in triplicate (HUD, MFD and HSI displays) because in the worst of weather conditions your chances of landing safely without ILS assistance are very slim. The easiest form of the display to use is the one which automatically appears on the HUD when you enter ILS coverage with the HUD in standard NAV mode (i.e. no weapon aiming displays). On the HUD ILS display, the aircraft datum in the centre is shown as a cross and a second, larger cross moves left, right, up and down to indicate which way it is to the centre of the ideal approach path. When you are in the centre of the path the two crosses are exactly superimposed.

For comparison you can call up the MFD ILS display by using the D key (MFD Function Select) to cycle through the possible displays. Here the ILS display shows fixed dashed crosshairs equivalent to the aircraft datum on the HUD, and moving solid crosshairs which correspond to the larger moving cross. This display also shows, clockwise from top left; Aircraft Heading, Bearing to the airfield (to runway midpoint), Range to the airfield in nautical miles (to runway midpoint) and Time-to-go in minutes and seconds. The two ILS needles on the HSI (Horizontal Situation Indicator) instrument are minute and hard to read; we only provide them as a last-ditch backup in case both HUD and MFD are unserviceable for a foul-weather landing.

Reading and Reacting to the ILS display

On the face of it, then, reaching the ideal approach path is simply a question of flying the aircraft towards the cross on the HUD. It's not quite that simple - there are two other points to bear in mind. The first is that the ILS display is only telling you where you are relative to the ideal approach path - it is NOT telling you if you're pointed in the right direction to stay there. To stay in the centre of

The HUD in ILS mode

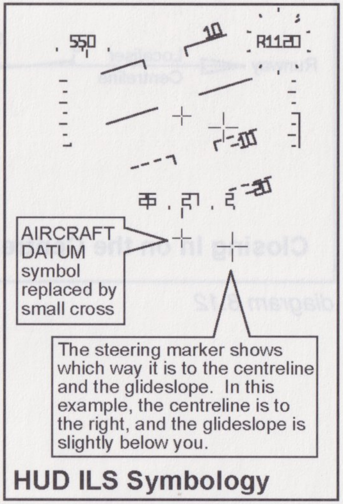
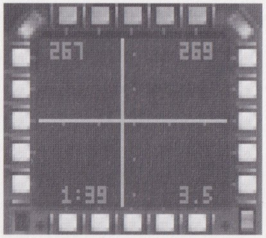
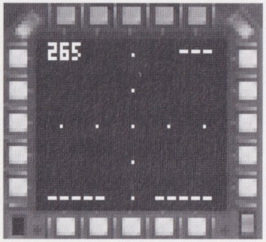


diagram 8.13



MFD - ILS active



MFD - ILS (not active)

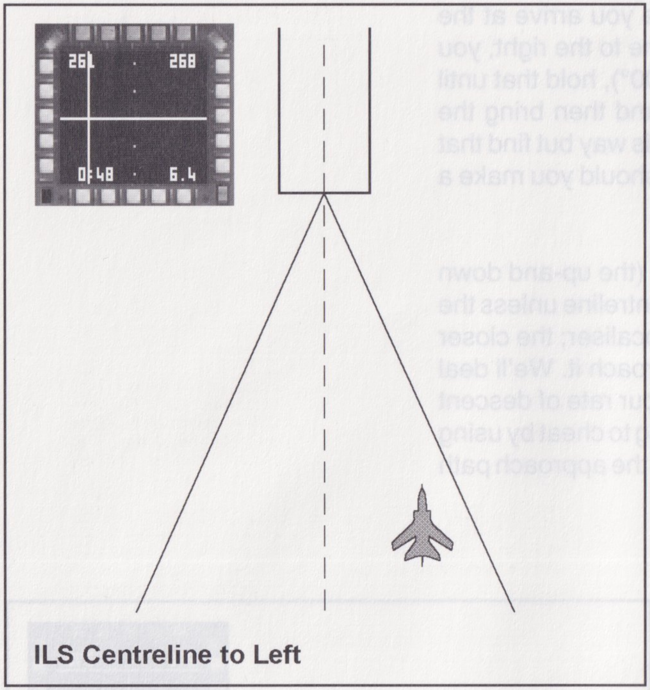


diagram 8.14

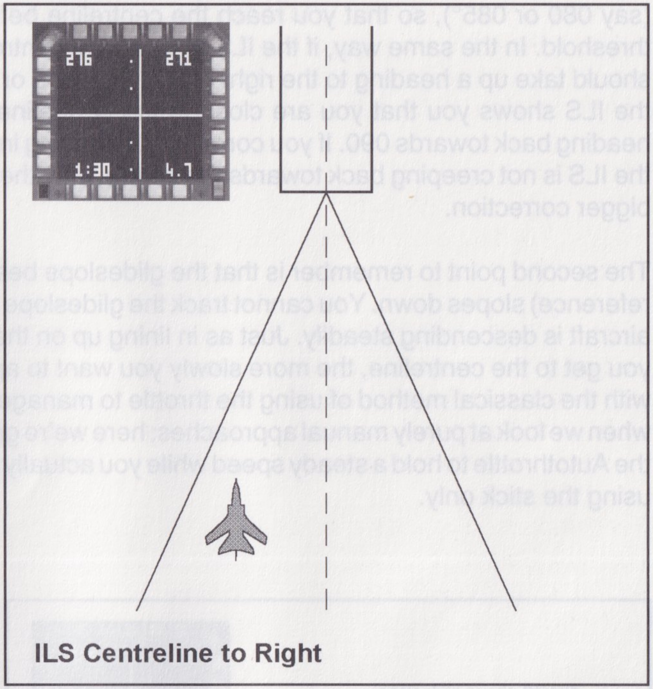


diagram 8.15

the localiser beam (the left-right reference) you need to be pointing in the same direction as the runway you're approaching. If you're landing on runway 09 the aircraft's got to be on a heading of 090° as well as in the centre of the beam. Don't make big, radical manoeuvres to try to reach the centre of the beam - the closer you get to it, the smaller your corrections should be.

This is a highly important point, and one which many people find difficult to grasp: if the ILS display is telling you that the runway centreline is off to the left of your current position, it's NOT telling you to keep turning left until you reach it. If you're approaching runway 09 and the ILS shows that the centreline is off to the left, what you should be doing is taking up a heading to the left of 090°

(say 080 or 085°), so that you reach the centreline before you arrive at the threshold. In the same way, if the ILS showed the centreline to the right, you should take up a heading to the right of 090 (say 095 or 100°), hold that until the ILS shows you that you are close to the centreline, and then bring the heading back towards 090. If you correct your heading in this way but find that the ILS is not creeping back towards the centre, only then should you make a bigger correction.

The second point to remember is that the glideslope beam (the up-and down reference) slopes down. You cannot track the glideslope centreline unless the aircraft is descending steadily. Just as in lining up on the localiser; the closer you get to the centreline, the more slowly you want to approach it. We'll deal with the classical method of using the throttle to manage your rate of descent when we look at purely manual approaches; here we're going to cheat by using the Autothrottle to hold a steady speed while you actually fly the approach path using the stick only.

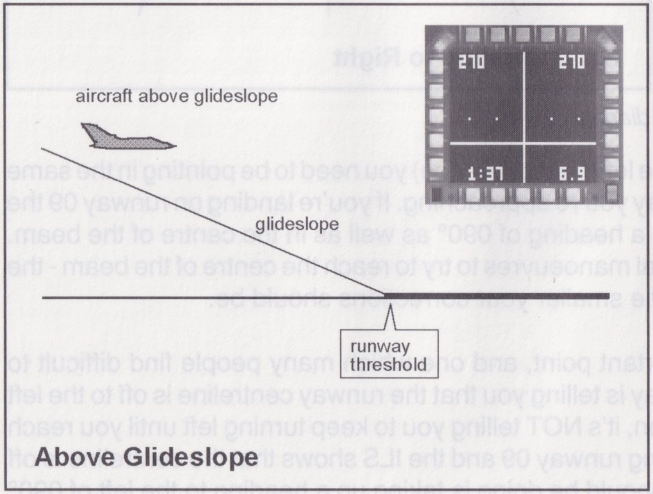


diagram 8.16

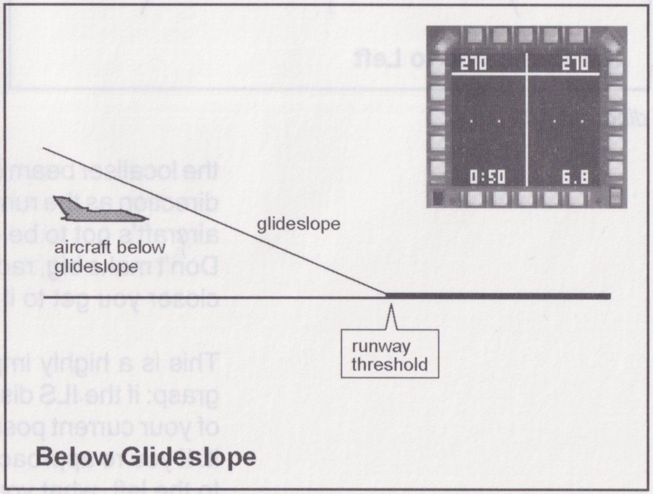


diagram 8.17

Don't be Hypnotised by the Instruments!

As you get closer to touchdown and the runway looms larger you should transfer your attention from the ILS cues to the outside world. The ILS is highly useful when the runway is distant, but in all except the very worst visibility the last stages of the approach will be much easier to fly by eye. It'll also be much easier to achieve the shortest possible touchdown and landing run.

Setting your Approach Speed

So what do we tell the Autothrottle? If you remember, approach speed is calculated by taking stalling speed in the current configuration and adding a percentage. Stalling speed for the Tornado depends on 1) Wing Sweep position, 2) Flap setting and 3) Aircraft weight, so there's a lot of scope for variation. We give a ready-reckoner approach speed table in the Aircrew Notes, but here's a simplified version of it predigested for three different weights:

Recommended Approach Speeds at 25° Wingsweep

Weight:	Flap Setting:			
	Zero	Man'vre	Mid	Full
Light	180	172	153	135
Medium	210	202	183	165
Heavy	248	240	221	203

Light case:	33000lb / 15000kg - Virtually empty aircraft
Medium case:	45000lb / 20400kg - No external stores, full internal fuel
Heavy case:	60000lb / 27200kg - Near maximum take-off weight

Note that we only give figures for 25° wingsweep here. You'd never expect to touch down with the wings in any other sweep position unless the sweep mechanism itself jammed - we'll try that later. While you can drastically speed up the process of approach and landing by coming in at higher speeds and decelerating at the last minute, don't try it until you really know what you're doing.

The medium-weight case is probably the most useful: set the Autothrottle to about 210 knots to bring you within flap-limiting speeds, lower the flaps all the way and then set 165-180 knots. Just be aware that this won't work if the aircraft is too heavy. If you're carrying more weight than this it would normally be sensible to dump some of it using the External Stores Jettison option before starting the approach.

When setting the Autothrottle as low as this you must remember that you're not far above stalling speed. If you manoeuvre hard to chase the localiser needle or point the nose high in the air to climb to the glidepath, your airspeed may fall to the danger point.

Another way of gauging the correct approach speed is to watch the Alpha (Angle of Attack) meter - either the HUD display or the mechanical guage next to it. If you're in the right speed range for an approach at your current weight, the reading should generally be somewhere between 8 and 12°. If it's higher than this then you're too slow, if lower then you're too fast. Check the Approach & Landing Emergencies section at the end of the Aircrew Notes for the figures to use in unusual cases.

Semi-automatic Approaches - Summing up

Provided that you understand what the ILS display is telling you, and you can fly the aircraft to centre it in the beams ON THE RUNWAY HEADING with the Autothrottle holding a sensible airspeed, you should arrive at the runway threshold in good shape for touchdown. Use the Landing Practice setup in the Simulator until you're confident that you can track the ILS by hand.

There is one further technique you may find helpful for making small corrections left or right to track the localiser - using the rudder controls. We haven't said much about the rudder so far, and we won't say much more, because in modern aircraft it's almost redundant as a manual control, and has a very limited effect at any but the lowest speeds. On the approach, however, it can be useful. Look up the rudder commands under Primary Flight Controls in the Control Summary.

MANUAL APPROACHES

Once you can fly a semi-automatic approach as described above, you've mastered the art of reading the ILS and acquired a feeling for the art of correcting into the centre of the beam without overshooting. There is a further challenge you may wish to take up: purely manual landings with and without the aid of the ILS. If you can do everything we've discussed so far, you should be able to handle this without too much trouble - and no self-respecting pilot should ever be satisfied until (s)he can land with the absolute minimum of artificial aids. The AFDS, the Autothrottle or the airfield ILS may be knocked out by battle damage. You may have to make an emergency landing on a airfield taxi-track or a road. In any of these cases you've got to be able to cope. If you can't, you can only eject - and throw away an extremely valuable aircraft.

Manual Approach with ILS

Here we're talking about flying an approach without using the Autothrottle. Managing speed at the same time as flying the approach adds considerably to the difficulty and demands a quite different flight technique. Normally you think in terms of controlling speed with the throttle and controlling rate of descent or climb by pointing the nose up or down. At the low speeds involved in flying an approach, however, it is actually easier to reverse this convention. Think in terms of controlling speed by raising the nose (to slow down) or lowering the nose (to speed up), and controlling rate of descent by opening the throttle (to descend more slowly) or closing the throttle (to descend faster).

Obviously there will be side effects; raising the nose will usually reduce your rate of descent as well as your airspeed, and so on, but these side effects are actually easier to deal with using the reversed convention of airspeed::pitch and rate-of-descent::thrust. Let's give some examples of how the process works:

1 Speed correct, but BELOW the glideslope

You respond by throttling up to raise the engine RPM figure one or two per cent. Now watch your airspeed. As soon as this starts rising above the target figure, raise the nose slightly to bring the speed back on target. The end result is that you're still at the correct approach speed, and you're descending more slowly than you were.

2 Speed correct, but ABOVE the glideslope

Throttle back a little. As the airspeed drops below the target, lower the nose a little to recover the speed.

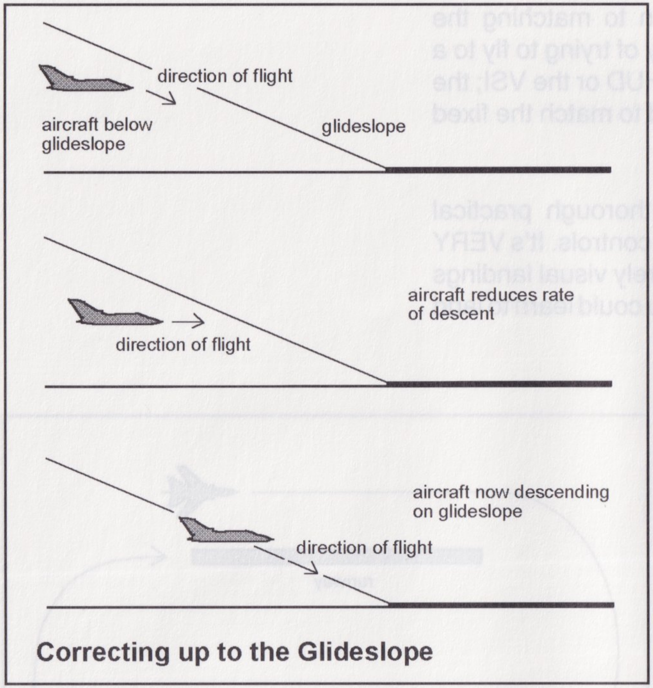
3 ON the glideslope, but speed LOW

Lower the nose slightly, and watch for the speed to start rising. As it reaches the correct figure, raise the nose again very slightly. If this leaves you below the glideslope refer to example 1.

4 ON the glideslope, but speed HIGH

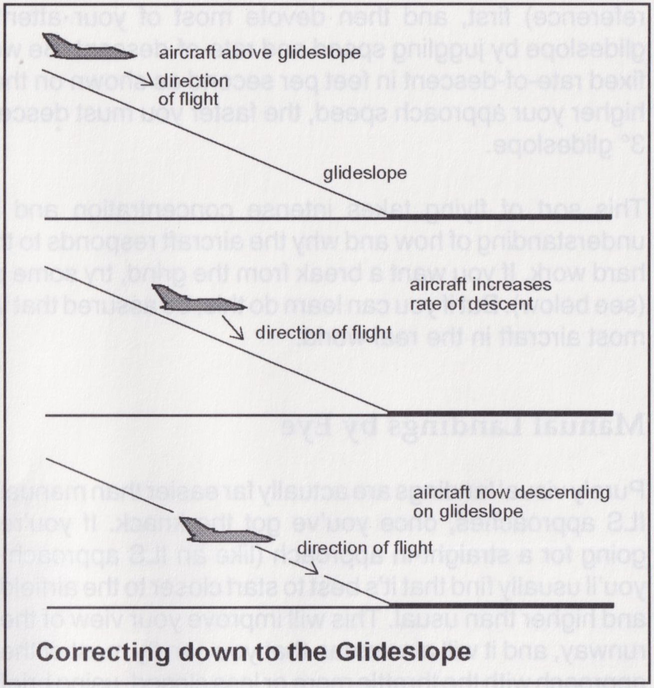
Raise the nose a little till the speed starts to drop, wait till you're close to the target speed and then lower it a fraction to stabilise at the new speed. If this leaves you above the glideslope, deal with the problem as in example 2.

It'll take a lot of practice in the Simulator before you can do this reliably. To make your initial attempts easier, use a higher approach speed than normal. This will give you more margin for error. You'll probably find that the largest problem is the time lag in engine response to throttle changes, and aircraft



Correcting up to the Glideslope

diagram 8.18



Correcting down to the Glideslope

diagram 8.19

response to the change in thrust. For this reason it's best to try to avoid large changes of throttle setting unless absolutely necessary. Having said that, there's no way to avoid one large throttle movement: your first action in the Simulator Landing Practice scenario should normally be to close the throttle completely (and use airbrakes) in order to lose speed. As your speed decays towards the chosen approach value you will need to open the throttle again, but it's best to do this in gradual stages, starting well above the approach speed.

Until you've got the feel of the situation it's best to be very, very cautious, and make the smallest possible control inputs. Line up on the localiser (left-right

reference) first, and then devote most of your attention to matching the glideslope by juggling speed and rate-of-descent. Be wary of trying to fly to a fixed rate-of-descent in feet per second as shown on the HUD or the VSI; the higher your approach speed, the faster you must descend to match the fixed 3° glideslope.

This sort of flying takes intense concentration and a thorough practical understanding of how and why the aircraft responds to the controls. It's VERY hard work. If you want a break from the grind, try some purely visual landings (see below). But if you can learn do this, be assured that you could learn to land most aircraft in the real world.

Manual Landings by Eye

Purely visual landings are actually far easier than manual ILS approaches, once you've got the knack. If you're going for a straight-in approach (like an ILS approach) you'll usually find that it's best to start closer to the airfield and higher than usual. This will improve your view of the runway, and it will also mean that you can fly most of the approach with the throttle more or less closed, using brief bursts of power to stretch your glide.

You will probably also find that it's easier if you fly most of the approach a little faster than usual, with manoeuvre or mid flap settings and the gear up. This means that you can drop the gear and the flaps at the last minute as extra airbrakes, rather than hang about on the edge of the stall point. Use the Angle of Attack to judge your approach speed.

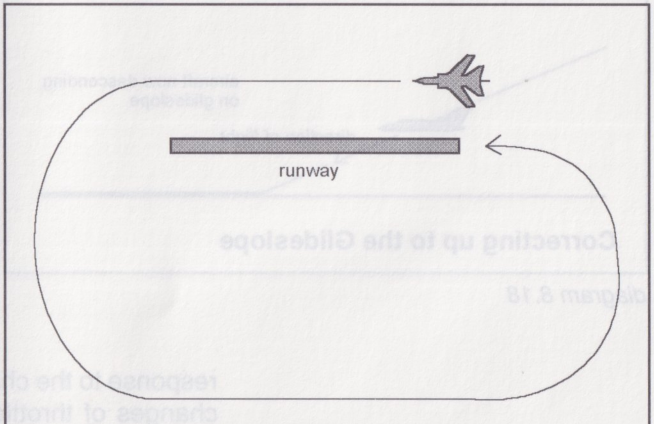


diagram 8.20

If you're really ambitious, you might try a standard military curved circuit approach. Lining up on the runway from the final 180° turn is more difficult than in real life because of the restricted and inflexible views available from the

cockpit - something which we can't do much about until Virtual Reality-style helmet-mounted displays become commonplace.

Once you become accustomed to visual, manual landings you'll probably find yourself doing it this way most of the time. The ILS is a godsend in poor visibility, but it takes a long time to fly the full distance at approach speeds. You can put the aircraft on the ground much faster for yourself - provided that you can see to do it.

LANDINGS AND WIND DIRECTION

Up to now we've more or less ignored the influence that wind speed and direction has on landing, but in the real world it's a major safety issue. The 'Landing Practice' Simulator exercise gives you still air, which is a very rare situation in real life. In practice the wind direction will dictate your take-off and landing direction and the length of ground-run required.

The reason isn't all that hard to understand. If an aircraft was flying straight and level at an Airspeed of 150 knots directly into a hurricane-force wind blowing at 150 knots, it would be hovering over a point on the ground. The Airspeed Indicator shows your speed through the air, which is itself moving over the ground as the wind blows. To take a more realistic (though still extreme) example, an aircraft flying directly into a 50-knot wind at an airspeed of 150 knots is actually travelling over the ground at 100 knots. If that aircraft flew at the same airspeed (150 knots) in the same direction as the 50-knot wind it would be travelling over the ground at 200 knots. In both cases, the wind speed and direction make no difference to the flying qualities of the aircraft - it's flying the way you would expect it to at an airspeed of 150 knots. The difference lies in how fast it's covering ground.

Speed over the ground makes at least two important differences when it comes to landing. The first is in the approach. If you're landing into the wind, subtracting its speed from your own, the approach will take longer and you'll

need a lower rate of descent than you would in still air. This may be tedious, but it's not unsafe. If you land with the wind behind you, adding its speed to yours, everything will happen faster and you'll need to descend faster than usual to stay on the glideslope. Rushing the process is clearly not desirable.

The other (and more important) difference comes when you touch down. When your wheels hit the runway airspeed ceases to matter (you're no longer flying), and groundspeed becomes all-important. Landing into the wind your groundspeed is lower and your landing run shorter. Landing downwind your groundspeed is higher and your braking distance increases. The choice should be obvious.

Wind direction also matters for take-off, for similar reasons. If your aircraft is standing on the runway facing into a 20-knot wind, it need only accelerate to a groundspeed of 130 knots before the Airspeed indicator shows 150 knots and you can rotate to lift off. If you started with a 20-knot wind blowing past the aircraft from behind, you'd need to roll a lot further to reach a groundspeed of 170 knots in order to have an airflow of 150 knots over the wing. Everything which flies and has a brain takes off and lands facing INTO wind whenever possible. If it isn't possible, you may be in trouble.

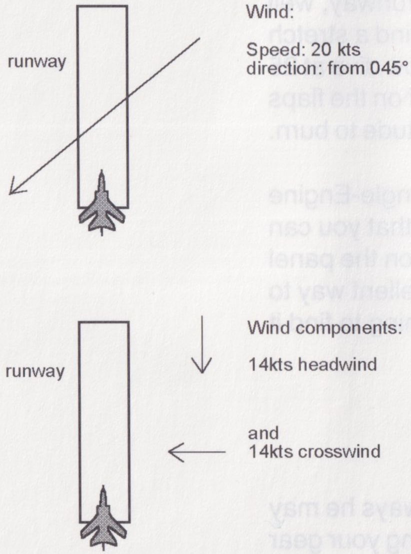
Crosswinds

When an airfield is built the designers do their best to line up the main (or only) runway with the prevailing wind in the area, so that most of the time aircraft will be able to take off and land directly into wind. Sometimes, however, geography and financial constraints make this impossible; the longest possible runway on the site just has to run in some other direction. The wind is also less than 100% reliable, and will blow from inconvenient directions at least a part of the time.

You can't usually suspend operations altogether because the wind isn't cooperating; you just have to make the best of it. Unless the wind is blowing across the runway exactly at right-angles, which it very rarely does, you can always resolve it into a component along the runway (a head-wind or tail-wind),

and a component across it, the crosswind *(see diagram 8.21)*. When the time comes to learn about the Mission Planner, you'll find that there's help available to analyse the situation and help you select sensible take-off and landing directions. Here and now we're concerned with how to deal with the practical results.

It shouldn't take much reflection to decide that you want to take off and land with a head-wind rather than a tail-wind. But whatever you do, you'll just have to live with the crosswind component. A crosswind component at take-off will make very little difference to a heavy and powerful aircraft like the Tornado, but a stiff crosswind will make a large difference to your approach.



Head-Wind and Cross-Wind Components

diagram 8.21

There's a Simulator exercise called 'Crosswind Landing Practice' which you can try out. You'll find that in order to fly a straight line down the centre of the beam you will need to keep the nose pointing a few degrees to the upwind side of the centreline. If you point the aircraft straight down the beam, it'll be blown sideways by the crosswind component. Be especially careful at and after touchdown when flying this sort of approach - you may need to do some brisk steering to avoid veering off the runway. If you can afford a good long roll after touchdown, you can mitigate the effects of a crosswind by flying a faster approach than usual. This will mean that you can point the nose closer to your intended path. Conversely, a slow approach with a heavy crosswind will be very difficult to fly accurately.

LANDING DAMAGED AIRCRAFT...

You can practice various emergencies quite easily in the Simulator. Want to try a wheels-up landing? Simple! Just leave the gear up. It is possible, but you must touch down very lightly. Lighten the aircraft as much as possible first. For a flapless landing, leave the flaps up. Pretend that the wing sweep mechanism has failed, and try landing with 45 or 67° sweep (check the Approach & Landing Emergencies data in the Aircrew Reference section first!). Try a landing with the engines at idle thrust - without touching the throttles.

For a real dead-stick landing, do a maximum jettison then light up full reheat to burn off the remaining internal fuel. Keep the aircraft at low level and that won't take long. When the engines flame out, zoom-climb the aircraft to turn as much speed as you can spare into altitude. If you can find a runway, well and good - if you can reach it. If not, it'll have to be a road. Try to find a stretch without bridges. Obviously the aircraft will glide furthest in a shallow dive at 25 sweep, but that's not saying much - no fast jet glides well. Hold off on the flaps and the gear to the very last minute unless you have speed or altitude to burn.

There is also a special-purpose Simulator mission called 'Single-Engine Handling' - try it. If you examine the Control Summary you'll find that you can turn off the HUD, the MFD or the back-seat Tab displays. Flying on the panel instruments without the HUD is difficult but possible, and an excellent way to put some excitement back into the job of landing if you're beginning to find it too easy.

...On Damaged Runways

Don't forget that while you're off trying to crater the enemy's runways he may visit your home airfield to return the compliment. Apart from leaving your gear up, it's hard to think of a more humiliating way to end an otherwise successful mission than to land perfectly and then run the aircraft into a hole on the roll-out. Keep your eyes open on the approach, and use the forward-looking camera at night. If your runway is damaged, you've either got to stop before,

land after or swerve around the craters - or land on another runway. If you don't want to divert or you can't for lack of fuel, you must either land on one of the long taxiways or use a disused runway (these are the ones with white crosses at the threshold). Provided that they haven't been damaged in the attack, these surfaces should be perfectly suitable, though respectively narrower and shorter than the main runway, and of course there's no ILS. Watch out for taxying aircraft on the taxiways and parked aircraft on the disused runways. In the Simulator there's nothing to stop you trying a landing like this at any time. If you really want to get into the spirit of the thing you might try attacking your own airfield and then landing - it'll give you a whole new perspective on JP233 attacks. In the last resort you can always try landing on a nearby road.

EMERGENCIES

Emergencies divide into two rough categories; recoverable ones which offer some prospect of saving the aircraft as well as yourself, and those where you must abandon the aircraft in order to save your life. The tricky part is deciding which kind of emergency you're facing, and doing so fast enough to take the appropriate action in time.

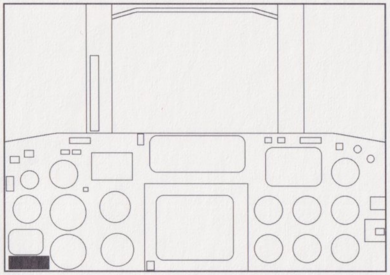
Emergencies include systems failures and loss of control for any reason. We've already dealt with stall recovery, and suggested Simulator exercises to practise landing with various equipment failures. If you make yourself familiar with the controls available you can simulate and try out a great many system failures, and the exercise can only do you good.

Here we'll discuss three topics: jettisoning stores to lighten the aircraft, ejection and spin recovery drill. Jettisoning weight will usually mean aborting your mission, but it will always improve the performance of the aircraft if you still have control. Ejection is always the right response in any of the following situations: Engine Fire, permanent loss of control at any altitude, any loss of control at low altitude. The Tornado will never spin unless the SPILS system

is disabled or damaged, but when it does the recovery technique is highly unconventional.

Jettison Options

There are three graduated jettison commands, and three matching lights on the Front Panel. In increasing order of severity these are:



Jettison Lights

Jettison External Tanks only

Releases the drop tanks on your inboard pylons to save weight and drag. If the tanks are empty then you improve performance and range at the expense of losing re-usable tanks, the supply of which is not infinite. If the tanks still contain fuel then the relative performance improvement will be far greater, but you will probably have sacrificed range or endurance. This may prevent you from completing your mission, or returning from it safely, but if a Tornado is involved in any kind of close air combat your chance of surviving, let alone winning, is not good unless you dump as much weight as possible.

The green Jettison light illuminates to confirm separation.

Jettison Tanks and Offensive Stores

This is the option you need if hard-pressed by an enemy fighter in close combat, or in the event of engine damage. It dumps all external stores except AIM9L air-to-air missiles for self-defence.

The amber and green Jettison lights illuminate to confirm separation.

Jettison All External Stores and Internal Fuel down to 1000 lbs. /450 kg.

This option is intended for use just before landing a damaged aircraft, if the situation demands it. All external stores are dumped without exception, and all internal fuel bar 1000 lbs with which to complete the approach, leaving you with an aircraft in its lightest possible powered configuration.

The red, amber and green Jettison lights will all illuminate to confirm that the stores are gone and the fuel dumped.

Ejection

Ejection itself is a very simple action. Once activated, the system thinks for itself and does its best to maximise your chances of survival right up to the point when it opens your parachute for you. However, it's still up to you to decide when to pull the handle. You must decide for yourself wether a) the situation is so dire that you must eject now or you definitely won't survive, b) with the aircraft in its current attitude you probably won't survive ejection, or c) the aircraft will probably stay in one piece, under control, for long enough to allow you to manoeuvre to improve your chance to survive or avoid capture.

There are two situations in which ejection is definitely the only way out. These are an engine fire, which (for our purposes) will always result in a catastrophic explosion within a few seconds, or a loss of control with no prospect of recovery before the aircraft hits the ground. If and when an engine fire is detected the warning system will go off and the condition will be flagged on the Warning Panel in the back cockpit. Loss of control can occur in many different ways, but you will probably be in no doubt when it occurs. All that remains is to decide whether your chances will be improved by waiting - and normally, they won't.

The Tornado's ejection seats, like those in almost all modern combat aircraft, have what is called a zero/zero capability - the zeros are for altitude and airspeed. In other words, you can eject from a motionless aircraft on the ground and expect to survive. The seat contains a rocket motor to lift you and throw you far enough away that a) your parachute has time to deploy before you hit the ground and b) with any luck you won't come straight back down on top of the burning wreckage of your aircraft. The seat is quite smart, and will do its best to tailor its response to the situation but there are unavoidable limits to what you can expect. Because the ejection system fires the seats upward from the cockpit, ejecting with the aircraft inverted is suicidal at low level.

At the other end of the scale, ejection at a high Mach number is also risky because of the appalling air blast. Another hazard is involved because high speed usually means high altitude. The seat mechanism contains an automatic opening device which will normally delay the deployment of your parachute till you have fallen to a survivable altitude (10000-20000 feet might be a common setting) and decelerated to a sensible speed. The mechanisms involved are simple, robust and highly reliable, but they are not immune to damage - and they are designed to fail safe if possible. For an automatic parachute opening device, failing safe means deploying the parachute sooner rather than later (or not at all). All parachutes open harder the higher the deployment altitude, and a high-speed opening at high altitude may cause serious injury or death through opening shock (even in the normal case this might involve a 20 G jolt), or through the risk of anoxia and exposure on the way down.

If time and the situation allow, the best way to maximise your chances is to eject at low speed (up to 300 knots, say) at a moderate altitude (say 10000 to 15000 feet). When all is sad and done, however, there are many situations where ejection is the only option you have left, and if you don't pull the handle straight away you won't get another chance.

SPILS, SPINS AND SPIN RECOVERY

The Tornado, like all modern combat aircraft, has a sophisticated flight control system. In simple aircraft the pilot's controls are directly connected to the control surfaces of the wings and tail, which are moved either directly by the pilot's muscles, or by a servo system which uses hydraulics to boost muscle-power. In more sophisticated aircraft like the Tornado, the pilot's controls are not directly connected to the control surfaces. Instead, the pilot uses the controls to tell the flight control system what he wants the aircraft to do, and the flight control system then decides for itself how to move the control surfaces in order to carry out the pilot's command.

Without systems of this sort, modern combat aircraft could never have achieved their current high standard of agility. They are agile because they are unstable; a small control surface movement can produce a radical change of attitude, and they have no inherent tendency to fly in a straight line, or even the right way up. Flying such an unstable aircraft by hand would be like walking a tightrope in a high wind; even if you could do it, the effort, concentration and stress would exhaust you in a few minutes. When the flight control system is working, it constantly senses the aircraft's departures from the commanded flightpath and makes minor adjustments of the control surfaces to correct them before the pilot even has time to notice.

Extra protection is often built into such a system to enable the pilot to manoeuvre the aircraft aggressively and confidently right up to the extreme limits of its performance (as in air combat), while the automatics keep the G load within the structural limits and monitor the angle of attack. If the aircraft stalls despite all their efforts, such systems will then do all they can to keep the aircraft stable till it regains flying speed. The system which provides this extra safeguard in the Tornado is called SPILS, standing for Spin Prevention and Incidence Limitation System.

Spinning

Spinning is a hazard associated with stalling. When the airflow over the wings and the tail breaks down the aircraft is left falling through the air rather than flying. If the aircraft is rolling or yawing (changing heading without banking) when control is lost, a complex combination of aerodynamic, inertial and gyroscopic forces may arise in which the whole aircraft either rotates constantly round one or more axes (a steady spin) or alternates between two unstable positions (an oscillatory spin). In this situation normal flight control just doesn't exist, and the aircraft is falling rapidly out of the sky.

Fast jets with swept wings have the most vicious spin characteristics of any aircraft, and some are impossible to recover - all the pilot can do is eject. When it is working, the SPILS system in the Tornado detects any incipient spin

problem at the stall point and acts to correct it before the spin can become established. Like any other system in the aircraft, however, the SPILS system may be disabled by combat damage or random failure. If this happens, any stall may develop into a spin - so you need to know how to recover once the spin has started.

Spin Recovery

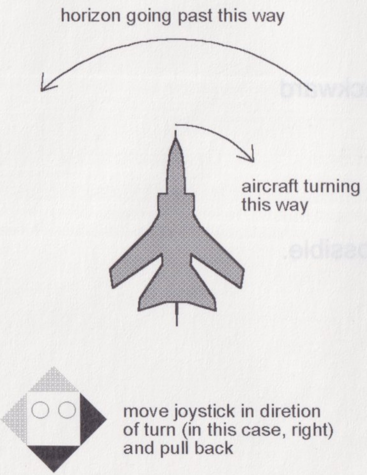
The Tornado's spinning characteristics and recovery drill are unusual for two reasons: first, it is a swing-wing aircraft and the nature of the spin changes with wing-sweep setting; second, it is unlike most other aircraft in that it has no aileron control surfaces on the wings, moving the tail surfaces differentially instead. If you are an experienced pilot of other aircraft types, DON'T ASSUME THAT YOU ALREADY KNOW THE RECOVERY DRILL!

Let's set up the problem in the Simulator. Select one of the Free Flight (Airborne) exercises. When you arrive in the cockpit, turn off the SPILS system. This should probably be done with the Control+I key combination, but check with the Control Summary for your machine (Secondary Flight Controls section). Be careful when doing this: just hit the key once, because the control toggles SPILS on/off and there's no indicator apart from the one on the warning panel in the back, which only illuminates when the system fails due to damage, and NOT when you switch it off deliberately. Now sweep the wings right back to 67°, cancel Autothrottle and go to full reheat (Slam Open twice). Let the aircraft accelerate to high speed on the level, then cancel reheat (just Slam Shut while in reheat), leaving the throttles at Max. Dry power (100% RPM). Pull the aircraft up into a near-vertical climb and take your hands off the controls.

The aircraft will zoom-climb to a high altitude, losing speed rapidly. At about 220 knots IAS you should see the nose begin to drop in the stall. Now apply full sideways stick - the direction doesn't matter. Suddenly the aircraft goes crazy - the HUD references and the instruments are all over the place and the horizon flashes past your nose at short intervals and strange angles. Hit F1 for an external view and you'll see that the aircraft is tumbling end over end in all

three axes as it falls. This is characteristic spinning behaviour when the wings are fully swept.

Now hit the Sweep Forward key twice, to bring the wings to 25 sweep. As the wings move forward you should see the wild tumble stabilise into a rapid rotation. If you move back to the cockpit you will see that the horizon is now fairly stable, but the aircraft is twirling like a propeller. In order to recover from the spin you must first identify which way the aircraft is rotating. This one excellent reason why you should bring the wings to 25 sweep first, because it is extremely difficult to tell which way you're going if the aircraft's in a full-blooded tumble.



Direction of Spin Rotation and Stick Movement for Recovery

diagram 8.22

Having identified which way you're turning: APPLY AND HOLD FULL BACKWARD STICK AND PRO-SPIN AILERON! In other words, hold the stick right back and to the side you would normally use to bank in the direction you're already turning. This is almost the exact opposite of the spin recovery drill used in most aircraft, which is classically performed by centering the stick, pushing it forward and applying opposite rudder. This classical procedure is utterly useless in a spinning Tornado.

Having applied full backward stick and pro-spin aileron, you will need to hold the stick in this position for a variable length of time, which will never be less than a couple of seconds and sometimes a good deal longer. Meanwhile watch the Altimeter and the Airspeed Indicator. Standard Operating Procedure in the Tornado is to eject immediately if the aircraft enters or continues a spin below 20000 (yes, twenty thousand) feet, but you may find that you are willing to continue recovery procedures below this height after you have some experience. The decision is entirely up to you.

In a steady spin the Airspeed Indicator will show a very low figure, far below normal flying speeds. One of the first signs that the recovery process is working will be a steady rise of speed. As the figure climbs towards the normal ranges you should also see that the rotation rate is slowing. When it stops, the aircraft is under control again, so immediately center the stick and (if you can still afford the height loss) push the nose down to accelerate faster.

Here's the Spin Recovery Procedure again, in short form:

Once you realise that the aircraft is spinning:

1 Eject immediately if there is insufficient height for a recovery (say 20000 feet), otherwise monitor altitude closely throughout the recovery process.

2 Command full forward sweep to 25°.

3 As soon as the direction of rotation is identified, apply and hold full backward stick and pro-spin aileron.

4 First sign of recovery will be a sustained increase in airspeed.

5 When rotation ceases, accelerate to a safe speed as quickly as possible.

EXTERNAL VIEWS

CHAPTER 9

EXTERNAL VIEWS

Although "stepping outside" as you are flying along is not exactly "authentic", a different perspective on a problem can often be useful and let's face it -it's fun! We have included no less than six "external views" that range from the commonplace to the spectacular. A status line at the bottom of the screen shows your aircraft speed, altitude etc.

(a) Tracking view

Perhaps most common of all is the option to "step outside" your cockpit and watch yourself fly along. When first selected, you will be positioned immediately behind your aircraft, following at a fixed distance. If your prefer, you may use the zoom in and out facility to adjust your perspective at either normal or fast rate.

When you've had enough of looking at tailpipes, try the "adjust tracking" controls. These allow you to swing your viewpoint around your aircraft in either direction, quickly or slowly, to give you a full 360° outside view. The "reset" option will position you behind the aircraft again and for good measure we have the "toggle lo/hi " feature which puts you level with your aircraft or slightly below it.

It is worth mentioning that when you leave Tracking View, your viewpoint and zoom level are stored so that when you next select this option your viewpoint appears just as you left it. For example, if you wish to watch an attack from a particular angle - say looking back at your aircraft from in front and below - you can set the viewpoint in advance, fly the attack, and then switch to Tracking View at the moment of weapon release.

(b) Satellite view

Select this option for a bird's eye view looking directly down onto your aircraft. Select again and you'll get a worm's eye view looking up from underneath! We do not recommend this second option when sitting on the runway as all you will

get is a close-up of the underside of the fuselage. The plan view though is very handy when taxiing around the airfield. We suggest that you zoom out to a reasonable height in order to see ahead of your aircraft.

(c) Remote view

This option allows you to hop outside and watch your aircraft from a fixed position. The viewpoint is fixed at the position of your aircraft at the moment of selection, and turns to follow your aircraft as you manoeuvre. This gives a superb impression of the true speed of your aircraft and is great fun if you wish to brush up your radio control techniques but it's very easy to get disorientated or lose sight of yourself altogether.....

(d) Drone view

"Drones" are the numerous computer-controlled aircraft and ground vehicles moving around the combat area simultaneously to yourself. By repeatedly pressing "drone view select" you may observe their activity and impress your friends. Zoom and track controls are available. You may also switch between allied and enemy drones, aircraft or ground vehicles.

(e) Weapon view

What better way to approach a target than alongside your weapon? Again, zoom and track adjust is available. Just prior to impact, air-to-ground weapons will switch to a plan view to help assess accuracy of delivery.

(f) Spectator view

Spectator view isn't strictly a separate view mode - it's an extra twist you can apply to any other view mode to achieve cinematic effects. When you select Spectator view, the viewpoint is 'frozen' in space wherever it happens to be at that moment (unless it's already a Spectator view), while the action carries on.

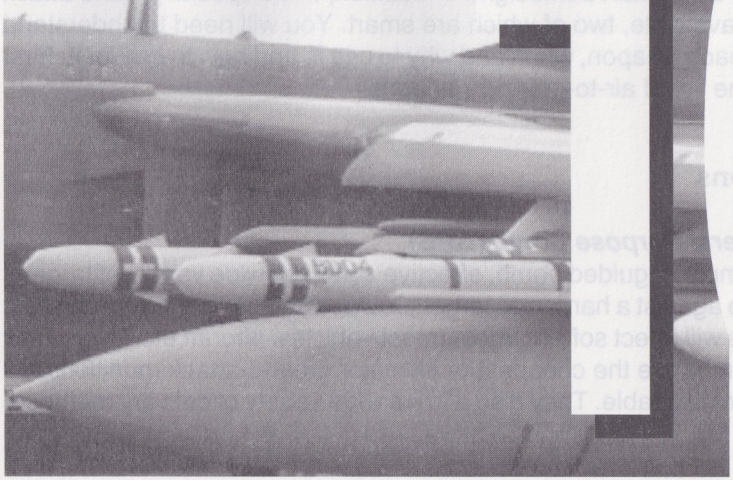
For example, you could call up the Tracking view, move it around ahead of the aircraft and zoom it out, then select Spectator view and watch the aircraft approach and flash past the stationary viewpoint. If you select Spectator view again as the aircraft passes, the viewpoint will be frozen at the aircraft position again, but this time watching it recede into the distance.

You can use the track adjust controls to rotate a Spectator view, and once you have set up the camera angle to your liking, return to the cockpit to fly the aircraft back into shot. Selecting "restore Spectator view" will put you back at your chosen spot to watch the effect.

If we tried to describe all the tricks you can play with Spectator view, it would rate a substantial chapter on its own. You'll have to experiment for yourself and use your own imagination.

WEAPONS CONVERSION

CHAPTER 10



WEAPONS CONVERSION

When a pilot under training has reached the stage where flying the aircraft to its safe limits does not demand 100% attention, it's time to start learning how to fight. The RAF call this phase of training Weapons Conversion. There are two very different subjects to cover: ground attack and air combat. In this chapter we'll also be looking at how to use the Tornado's radar in both its air and ground modes, and the Radar Warning Receiver. In the process we'll be considering a variety of tactical and operational problems.

AIR-TO-GROUND

The Tornado IDS was built to deliver the largest practical load of the cheapest, simplest weapons as accurately as possible regardless of weather and visibility. You may well be surprised at how accurately simple 'dumb' bombs can be placed by a smart bombsight. In addition, three special ground attack weapons are available, two of which are smart. You will need to understand the nature of each weapon, when and why to use it, and how to deliver it. First we'll look at the list of air-to-ground weapons.

The Weapons

1000 lb. General Purpose Bomb (GPB)
A plain and simple unguided bomb, effective against a wide variety of targets. Quite effective against a hardened target provided you can hit it, and the blast and fragments will affect softer targets (most vehicles, aircraft etc.) over a fair radius. GP bombs are the cheapest of all major ground-attack munitions, so large stocks are available. They also allow a wide variety of delivery methods,

so a good deal of flexibility is available in trading off accuracy against risk. Usually delivered four at a time.

1000 lb. Retarded Bomb (RET)

These are 1000 lb. GP bombs fitted with an alternative tail section incorporating a braking parachute. This means that they can be dropped safely from much lower altitudes than GP bombs, since the aircraft is much further ahead of the bomb by the time it hits the ground *(see diagram 10.1)*. Minimum dropping

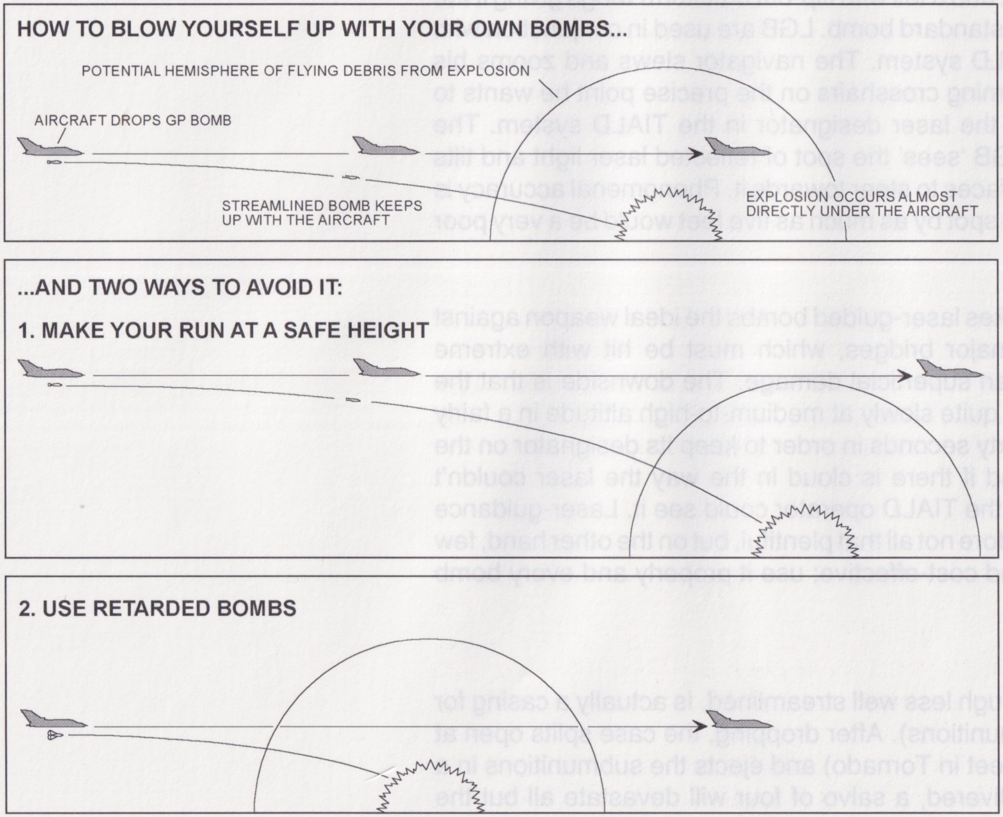


diagram 10.1

height for Retarded Bombs is 100 feet (just enough time for the fuse to arm), as against 1000 feet for unretarded GP bombs. Because the retarder kit is a cheap and simple fitting for a cheap and simple bomb, they are usually in good supply.

1000 lb. Laser Guided Bombs (LGB)
The original 'smart' bomb. This is actually another special kit fitting for a standard bomb carcase, providing a nose assembly containing the laser seeker and control surfaces, and a tail with flip-out cruciform wings giving it the ability to glide further than a standard bomb. LGB are used in conjunction with the launching aircraft's TIALD system. The navigator slews and zooms his camera view to place the aiming crosshairs on the precise point he wants to hit, which is illuminated by the laser designator in the TIALD system. The seeker in the nose of the LGB 'sees' the spot of reflected laser light and tilts the bomb's nose control surfaces to steer towards it. Phenomenal accuracy is possible - missing the target spot by as much as five feet would be a very poor performance.

This degree of accuracy makes laser-guided bombs the ideal weapon against hardened installations or major bridges, which must be hit with extreme precision to cause more than superficial damage. The downside is that the designating aircraft must fly quite slowly at medium-to-high altitude in a fairly straight line for twenty to thirty seconds in order to keep its designator on the target till the bomb hits, and if there is cloud in the way the laser couldn't illuminate the target even if the TIALD operator could see it. Laser-guidance kits are not cheap, and therefore not all that plentiful, but on the other hand, few weapons are as efficient and cost-effective; use it properly and every bomb scores a direct hit.

BL755 Cluster Bomb
Looks like a plain bomb, though less well streamlined. Is actually a casing for many smaller bombs (submunitions). After dropping, the case splits open at a preset height (set at 150 feet in Tornado) and ejects the submunitions in a dense cloud. If properly delivered, a salvo of four will devastate all but the hardest targets in a 'footprint' perhaps 100 feet across by 300 feet long. This

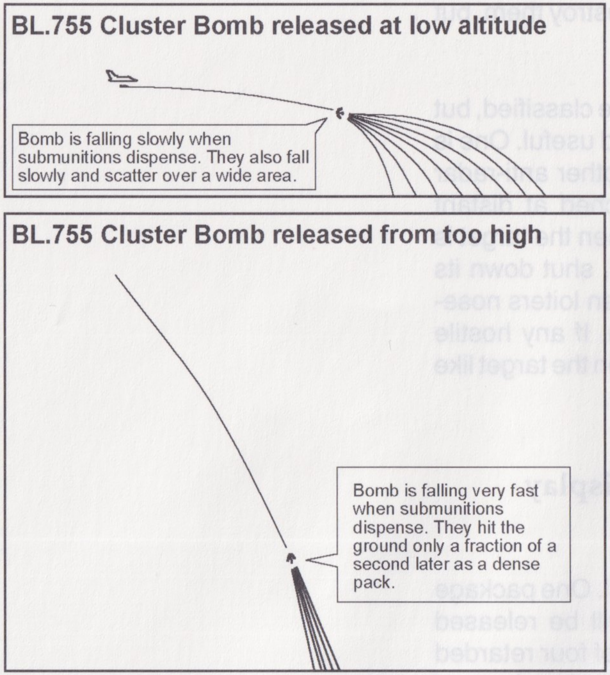


diagram 10.2

is the weapon of choice against groups of vehicles or parked aircraft. Its main drawback is that it must be delivered from about 200 feet for maximum effect *(see diagram 10.2)*.

JP.233 Dispensers
This is the mother and father of all runway-attack systems, the Tornado version comprising two giant pods weighing a total of nearly five tons! The pods contain two types of submunition: 60 large (56 lb.) SG.357 runway penetrators and 430 small HB.876 'area-denial' mines, both types parachute-retarded. As the aircraft overflies the runway, the submunitions are continuously ejected in a stream. When the runway-penetrators reach the surface, a shaped charge punches a small hole right through the concrete and a second charge is then fired into the hole, exploding beneath to crack and 'heave' the surface over as wide an area as possible. This type of damage is far more difficult and time-consuming to repair than a simple crater. Meanwhile the smaller mines land softly, discard their parachutes and spring upright, deterring and delaying repair through the deadly danger they present to men and vehicles.

JP.233 will make a really impressive mess of any runway if used properly. Its main disadvantage is the fact that the delivering aircraft has to overfly the target at low level holding a straight course for the four seconds needed to dispense the whole load - manoeuvering strews the things all over the place! It is also a heavy, draggy load for the aircraft, though the pods jettison automatically when empty.

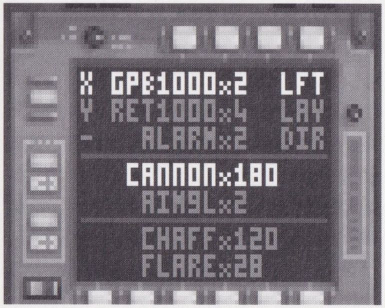
ALARM (Air Launched Anti-Radiation Missile)
ALARM is probably the most capable and sophisticated missile of its type currently in service (the US Tacit Rainbow project had even more ambitious aims, but died the death of a thousand budget cuts). Like any other anti-radiation missile ALARM homes on the transmissions of enemy ground radars

(EWR, search, SAM or AAA radars, for example) in order to destroy them, but it is far more resourceful than most.

ALARM has many different operating modes, some of which are classified, but we have implemented two which seem most characteristic and useful. One is a simple Direct mode, allowing ALARM to be used like any other anti-radar missile. In the other mode (Indirect) ALARM can be launched at distant suspected targets before you reach them or they see you. When the target is reached, the missile will zoom-climb to a point high above it, shut down its rocket motor (if it's still burning) and deploy a parachute. It then loiters nose-down, descending slowly and scanning the ground beneath. If any hostile radar is switched on, ALARM jettisons the parachute and falls on the target like a guided bomb.

Weapon Packages and the Stores Management Display (SMD)

Weapons for ground attack are grouped together in 'Packages'. One package contains all the weapons intended for one target, which will be released together as a salvo. You might, for example, load a package of four retarded bombs for a planned attack on airfield installations, and a second package of two BL.755 to attack targets of opportunity. The maximum number of weapons in a single package is four, and all must be of the same type - if they weren't, the bombsight would lose its accuracy because different weapons have different ballistic properties.



Stores Management Display

The content and status of any weapon Packages loaded can be seen on the Stores Management Display (SMD), bottom centre in the rear panel, where each of the top three lines can describe a single package. Suppose that the top line reads:

X GPB1000x4 LFT

This specifies from left to right the target, if any, for which the package is intended (X), the type of weapon (GPB1000), the number in the package (x4) and the Delivery Mode selected (LFT). The Delivery Mode specifies whether you intend to use manual or automatic release, a laydown or loft trajectory or a laser-guided attack. Some weapons, like JP.233, have only one delivery mode available. Others, like GP bombs, offer several options. When you start your attack run and flip the 'arm air to ground weapon' switch, the HUD will display different aiming cues according to the delivery mode selected. We will explore the various delivery mode options later, in detail.

Packages are created at the Mission Planning stage, either when you plan an attack on a specific target, or when you use the Payload window to create packages to use against Targets of Opportunity. If you planned attacks on two targets (X and Y) in one mission, and then loaded one more package for opportunity targets, when you looked at the SMD the first line would show the package for target X, the second line the package for target Y, and the third line the Target of Opportunity package, with a dash ("-") on the left rather than a letter.

The currently selected Package is shown highlighted. When you turn the arming switch on, this is the package that will be used in the attack, and the appropriate line on the SMD will flash continuously. When the package is released the Arm status cancels itself, the HUD resets to its normal nav mode, the package disappears from the SMD and the next package is selected and highlighted, ready to be armed.

You may override both the assignment of packages and the delivery modes, attacking any target with any package, using any delivery mode suitable for the weapons in the package. Hitting the K key will select and highlight the next package down the list, or skip from the last to the first. Hitting the L key will cycle through the available delivery modes for the currently selected package. You cannot do either of these things when the arming switch is on - if you want to change package or delivery mode you must hit 'Cancel Arm' first.

The Delivery Modes

This section provides a brief summary description of the various methods of placing freefall bombs on the target. After this familiarisation, we'll go through a complete hands-on exercise with each weapon and mode in turn.

Manual (SMD shows MAN)

This is a simple 'point and shoot' system intended for snap attacks on targets of opportunity. The HUD provides a bombsight, but aiming and release are entirely manual.

GP bombs, retarded bombs, BL755 and laser-guided bombs (unguided) can all use manual delivery.

Laydown (SMD shows LAY)

Targets for this delivery mode must be entered into the navigation systems, either at the mission planning stage or 'on the fly', using the Ground radar or the Scrollable Map display. The HUD shows the bombsight and a marker over the target, and the attack run can be flown manually or under AFDS control. The exact moment of weapon release is automatically calculated, but the weapons cannot be released unless one of the crew is holding down the Commit button.

Strictly speaking, a laydown delivery means releasing the bombs with the aircraft flying straight and level, but the bombsight systems will handle dive attacks or shallow lofts perfectly well in this mode.

GP bombs, retarded bombs, BL.755 and laser-guided bombs (unguided) can all be delivered in Laydown mode.

Loft (SMD shows LFT)

Targets for loft attacks must be known to the nav systems, as for Laydown mode. This type of attack is sometimes also called 'toss-bombing', because the bombs are thrown rather than dropped. The aircraft starts its attack run a good way out from the target, and while it is still miles away it pulls sharply up

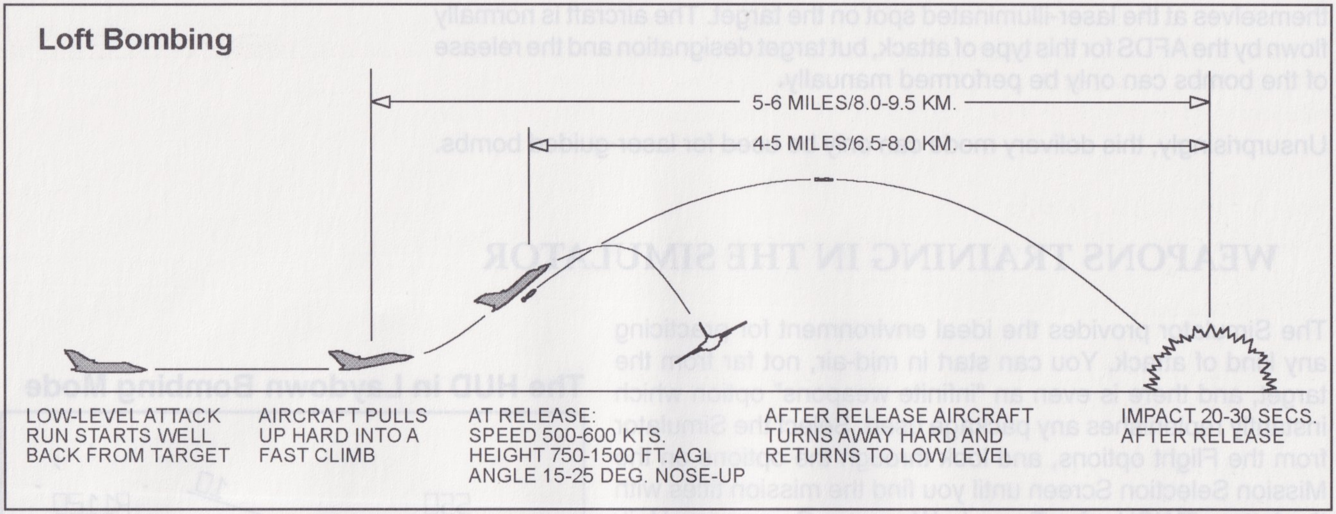


diagram 10.3

into a climb. The bombs are released in the climb and the aircraft is free to go, while the bombs fly on for several miles, rising and then falling onto the target in a trajectory like that of a long-range artillery shell. The bombsight cues on the HUD are quite different from the Manual or Laydown sights, and the attack profile can only be flown manually - unfortunately the AFDS can't fly the pull-up for you. Release is automatic, but only permitted if the Commit button is held down.

BL.755 cluster bombs are too aerodynamically 'unclean' to be lofted accurately, and lofting retarded bombs would make about as much sense as trying to pole-vault with a ball and chain round your ankle, so Loft delivery is only available for GP bombs and (unguided) laser-guided bombs.

Laser-Guided (SMD shows LGB)

An LGB attack is run entirely by the navigator, who must use the TIALD sytem to aim the laser designator at the precise spot he wants to hit. The laser-guided bombs are normally released in level flight at over 20000 feet, in order to allow the TIALD system the widest possible view, and after release they aim

themselves at the laser-illuminated spot on the target. The aircraft is normally flown by the AFDS for this type of attack, but target designation and the release of the bombs can only be performed manually.

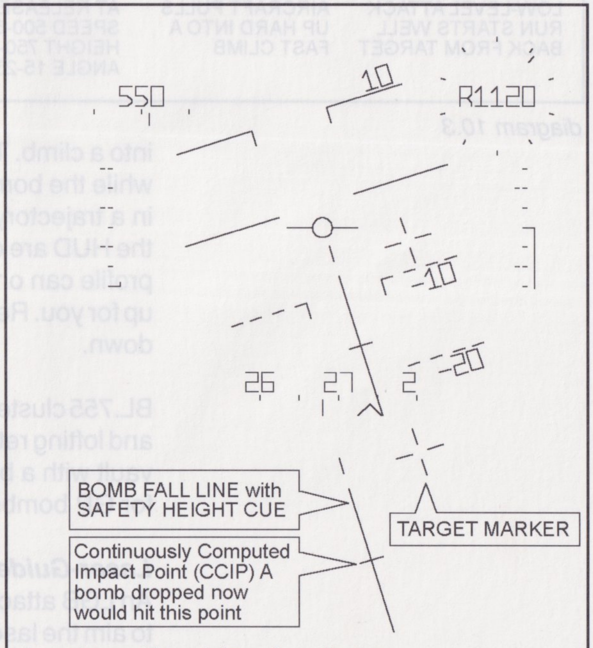
Unsurprisingly, this delivery mode can only be used for laser-guided bombs.

WEAPONS TRAINING IN THE SIMULATOR

The Simulator provides the ideal environment for practicing any kind of attack. You can start in mid-air, not far from the target, and there is even an "infinite weapons" option which instantly replenishes any package used. Select the Simulator from the Flight options, and look through the options on the Mission Selection Screen until you find the mission titles with the letters TWCU - for Tornado Weapons Conversion Unit. Select the first of these, titled 'IDS - TWCU - Freefall Bombs'. Make sure that the Simulator Options switch for Infinite Weapons is ON. Now Commit, and you will move straight to the aircraft, in flight. Engage the AFDS in Track mode - you will find yourself Terrain-Following at a ride height of 1000 feet.

Switch to the back seat and you will see from the Track display on the left Tab that the aircraft is approaching the Initial Point for an attack on target X. On the SMD you will see that the first package is selected; four GP bombs for Laydown delivery. There are two other packages loaded, one with two retarded bombs, and one with two BL.755 cluster bombs. For the moment, we're going to attack target X as planned, with the four GP bombs.

The HUD in Laydown Bombing Mode

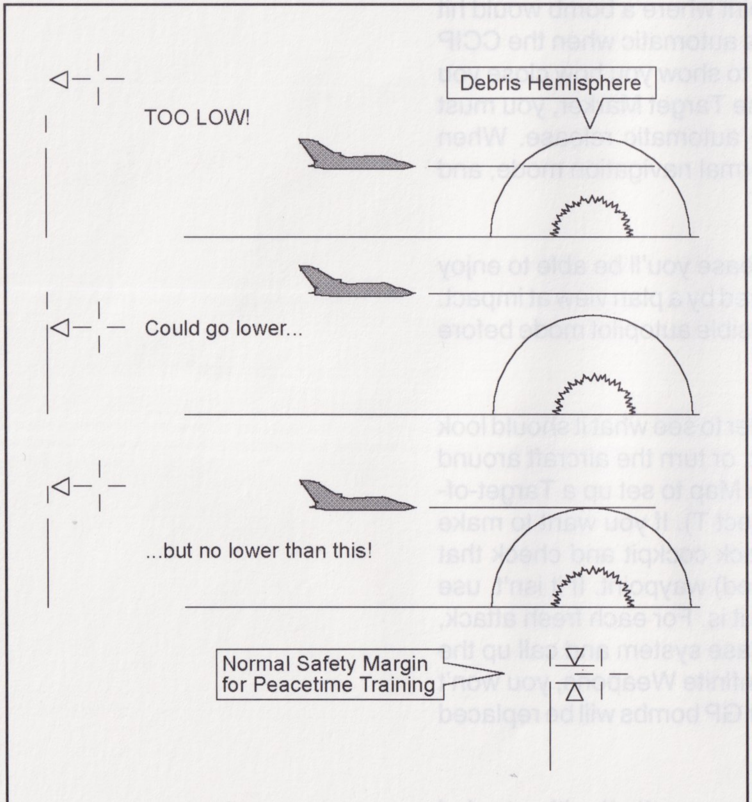


Laydown Bombing Symbology

diagram 10.4

Laydown Attack (LAY on SMD)

Laydown bombing is 'traditional' bombing, where the aircraft flies more or less straight and level over the target to release its bombs. Lining up on the target is the responsibility of the pilot (or the AFDS in Track mode), but the exact moment of bomb release is controlled automatically by the bombsight. The automatic release will not occur, however, unless the pilot or navigator permits it by holding down the Commit button. Laydown bombing is potentially very accurate at low level, since most pilots find it quite easy to line the aircraft up on the target, whereas judging the exact moment of release by eye is difficult to do consistently.



The Safety Height Cue for Laydown Bombing

diagram 10.5

Wait until the aircraft passes the Initial Point and starts turning towards X. The first thing to do is hit the 'arm air-to-ground' Switch, which you can do from either seat. From the back seat, you'll see the selected package on the SMD start flashing. In the front seat you'll see the Late Arm Switch cover raised, and the HUD mode will change to show the Bomb Fall Line, the CCIP (Continuously Computed Impact Point), and the Target Marker, which may well be partly hidden behind the Bomb Fall Line (*see diagram 10.4* to find out which is which).

For the moment the autopilot has control, but to do this manually, your first step would be to line up the Bomb Fall Line so that it passes through the Target Marker. The upper end of the Bomb Fall Line provides you with a Safety Height Cue, so that the aircraft isn't damaged by flying debris as the bomb goes off. You can see how this works in *diagram 10.5*. If you can't see the Bomb

Fall Line at all, you're far too low - it's disappeared off the bottom edge of the HUD! The ideal minimum height attack is flown with the top of the line right in the centre of the Target Marker, but for now you might want to allow the normal training safety margin, with the Target Marker in the gap below the top of the Bomb Fall Line.

The CCIP is the other element of the bombsight symbology. The point where the CCIP line crosses the Bomb Fall Line is the point where a bomb would hit if released now. In Laydown attacks, the release is automatic when the CCIP reaches the Target Marker, but the symbol serves to show you how close you are to release. Shortly before the CCIP reaches the Target Marker, you must press and hold the Commit button to permit the automatic release. When release takes place, the HUD changes back to normal navigation mode, and the Late Arm Switch flips back down.

If you hit the Weapon View key just after bomb release you'll be able to enjoy a bomb's eye view of the approaching target, followed by a plan view at impact. It's a good idea to ensure that the aircraft is in a sensible autopilot mode before you go sightseeing.

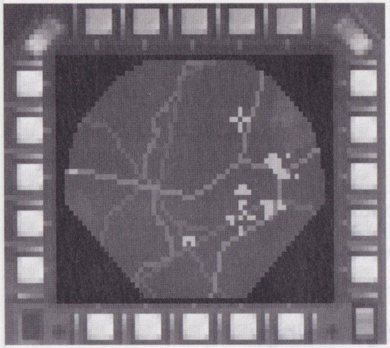
Having flown the attack under automatic pilot in order to see what it should look like, try it again manually. You can quit and restart, or turn the aircraft around and come back to X, or you can use the Scrollable Map to set up a Target-of-Opportunity waypoint to attack (don't forget to select T). If you want to make another pass on X, you'll need to hop into the back cockpit and check that waypoint X is still the currently selected (highlighted) waypoint. If it isn't, use the ' skip to next waypoint' key to cycle round until it is. For each fresh attack, you'll need to hit the arming switch to arm the release system and call up the bombsight symbology. Because you've selected Infinite Weapons, you won't need to make any new selections on the SMD - your GP bombs will be replaced the moment they're dropped.

Once you're comfortable with the bombsight, try the same attack with retarded bombs and BL.755 cluster bombs. Just use the [K] key to highlight the right package, but remember that you can't do this while the arming switch is ON.

The main difference you'll notice is that the Safety Heights for these two weapons are much lower than for GP bombs.

We talked in Advanced Flying Training about how to set a Target-of-Opportunity waypoint using the Scrollable map. There are two other ways to set a ToO waypoint, one of which is to use the Ground Radar, which we'll look at here.

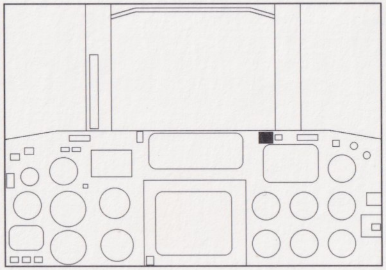
Designating a Target of Opportunity on the Ground Radar



MFD Ground Radar Display

This can be done from the front or back seat. Hit the R key to turn on the radar and show the radar image on the centre MFD. This is not a pure radar image but a synthetic composite. The landscape and fixed objects 'known' to the digital map system are always shown in dim green shades. When the radar detects an object which is not in the map database it displays it as a bright green dot. This is especially useful for finding vehicles (including SAM and AAA defences) and trains. Note that the radar can't see through hills. In the 'dead ground' behind a crest the display will show you only stored map data.

The mouse is used to control a designator cross which can be moved around the display - check that the MFD's green Mouse Active light is on, and if not, use the Tab key to turn it on. Just as with the Local Map display, the radar display can be zoomed in or out by clicking left or right mouse buttons with the Ctrl key held down, and targets are designated by clicking left or cancelled by clicking right.



Radar ON Light

Remember that using the ground radar may draw the attention of the enemy, if he hasn't already seen you. If you select another MFD display while the radar is on, there is a warning light on the panel to remind you that your radar is still transmitting. Always turn the radar off if you don't need it.

Manual Delivery (MAN on SMD)

This is a simple 'point-and-shoot' system intended for snap attacks on targets of opportunity when there is no time to designate or the target is moving. The HUD displays the Bomb Fall Line and the CCIP (Continuously Computed Impact Point) across it, showing where the bombsight thinks your bombs would go if released at this moment. No Target Marker is shown, because you haven't told the navigation systems where the target is. You just fly the aircraft to place your visually selected target at the intersection of the two lines, and then press the Commit button to drop the bombs. The important difference between the symbology used here and in the Laydown mode is in the way you interpret the Safety Height cue. In Laydown mode you compare the top of the Bomb Fall Line with the position of the Target Marker, but in Manual mode there is no target marker, so you compare the top of the Bomb Fall Line with the position of the CCIP *(see diagram 10.6)*. At low level you can achieve quite reasonable accuracy in Manual mode, but it's not exactly precision bombing.

The HUD in Manual Bombing Mode

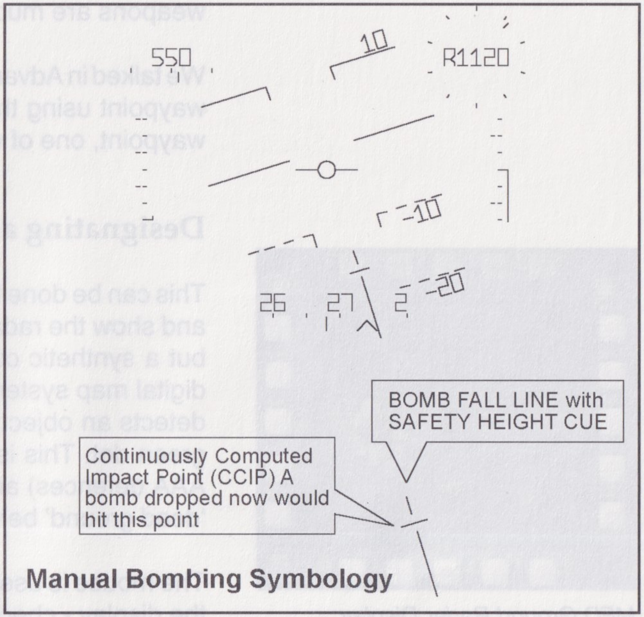
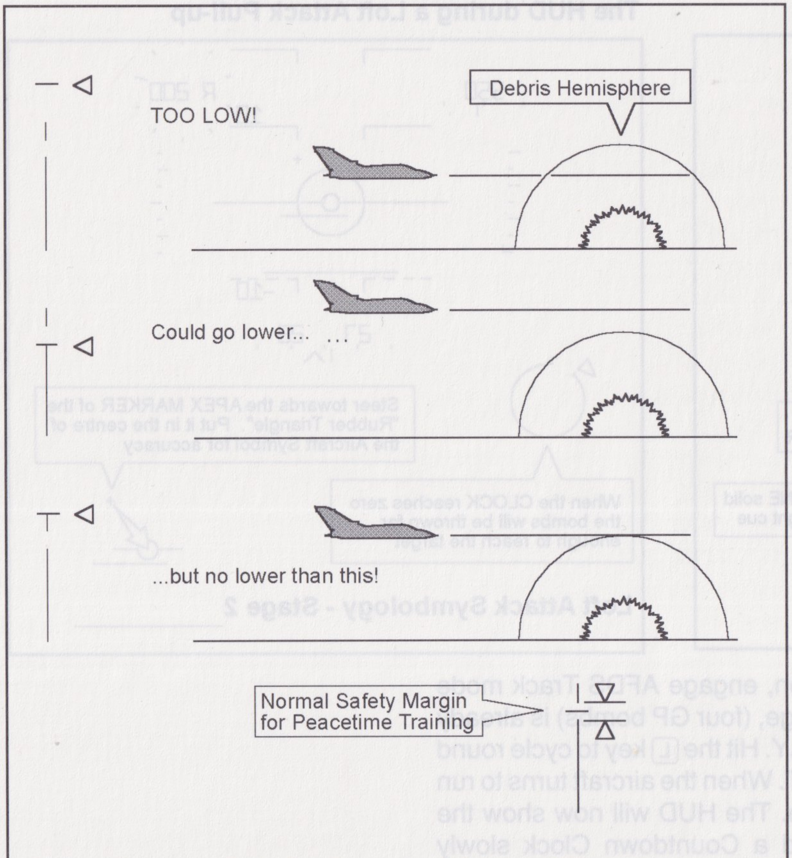


diagram 10.6

To change the delivery mode; go to the back cockpit and highlight the package you want to use using the K key, then hit the L key repeatedly to cycle throught the delivery mode options for that package until you reach MAN. As with any weapon delivery mode, you must Arm before you can drop the package.

Loft Delivery (LFT on SMD)

A Loft attack (you might have heard this called 'toss-bombing') also requires that the target position should be known to the navigation systems. A Loft attack comes in two phases: in the first you run in at low level and fairly high speed, starting a good distance (say 10 miles) from the target; you line up the



The Safety Height Cue for Manual Bombing

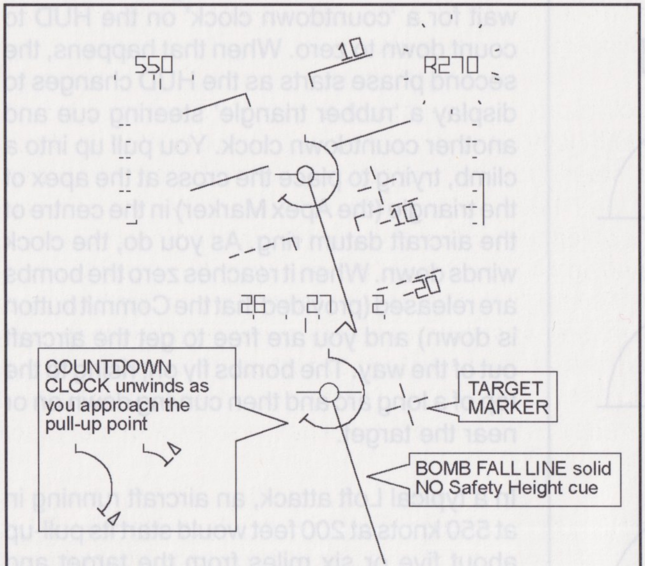
diagram 10-7

Bomb Fall Line with the Target Marker and wait for a 'countdown clock' on the HUD to count down to zero. When that happens, the second phase starts as the HUD changes to display a 'rubber triangle' steering cue and another countdown clock. You pull up into a climb, trying to place the cross at the apex of the triangle (the Apex Marker) in the centre of the aircraft datum ring. As you do, the clock winds down. When it reaches zero the bombs are released (provided that the Commit button is down) and you are free to get the aircraft out of the way. The bombs fly on, rising to the top of a long arc and then curving down on or near the target.

In a typical Loft attack, an aircraft running in at 550 knots at 200 feet would start its pull-up about five or six miles from the target and release its bombs just below 1000 feet, climbing at an angle of just over 20° - still four or five miles from the target. The bombs would take about 20-25 seconds to reach the target, climbing to 8-9000 feet before they start to descend.

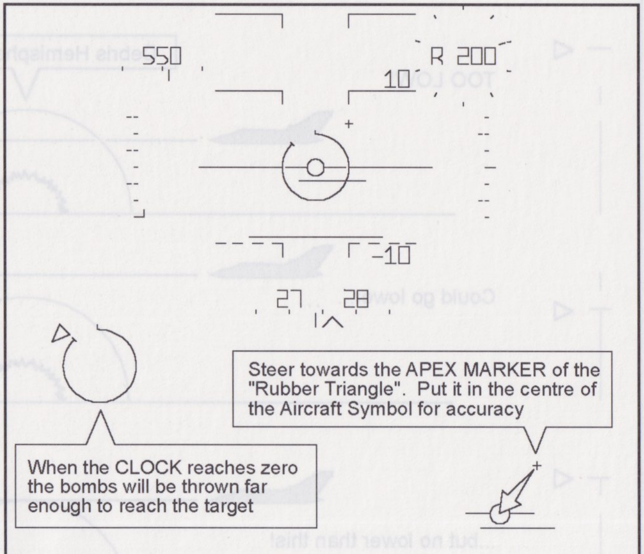
In a Loft attack, the bombs travel a very long way from the release point with no form of guidance, so absolute accuracy can't be guaranteed. In practice, however, you'll be amazed at how much accuracy is possible. Nonetheless, Loft bombing is not recommended for precision attacks. The great advantage of this form of attack is that the aircraft need not overfly the target, and may never even come within range of its defences.

The HUD during run-in for a Loft Attack



Loft Attack Symbology - Stage 1

The HUD during a Loft Attack Pull-up



Loft Attack Symbology - Stage 2

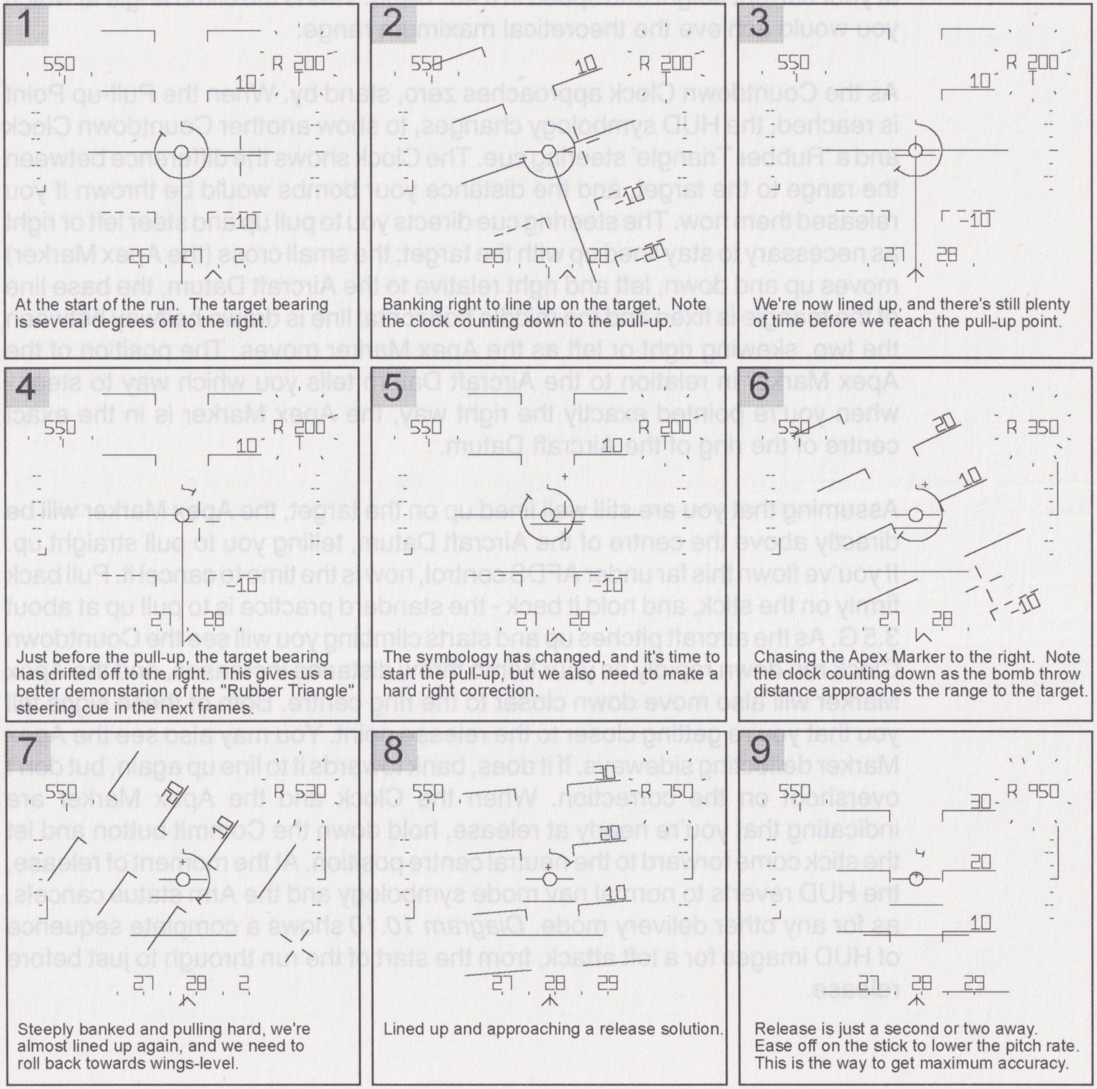
Restart the Simulator 'Freefall Bombs' mission, engage AFDS Track mode and switch to the back cockpit. The first package, (four GP bombs) is already selected and the delivery mode is shown as LAY. Hit the L key to cycle round the delivery options until the display shows LFT. When the aircraft turns to run in on target waypoint X, hit the arming switch. The HUD will now show the Target Marker, a solid Bomb Fall Line, and a Countdown Clock slowly unwinding anti-clockwise around the Aircraft Datum. Use the Bomb Fall Line to line up on the Target Marker, or let the AFDS do it in Track Mode, and whether manually or under AFDS, set your altitude to about 200 feet and your airspeed to about 550 knots. The Clock is counting down to the point where you start pulling up into a climb in order to loft the bombs. This point, the Pull-up Point, is constantly recalculated on the basis of range to the target, speed (the faster you're flying, the further you can throw the bomb) and altitude (the higher you are, the further the bomb will fly). The Pull-up Point is determined by the

maximum range at which your lofted bombs could reach the target if released at your current height and speed in a 45° climb. This is the climb angle at which you would achieve the theoretical maximum range.

As the Countdown Clock approaches zero, stand by. When the Pull-up Point is reached, the HUD symbology changes, to show another Countdown Clock and a 'Rubber Triangle' steering cue. The Clock shows the difference between the range to the target, and the distance your bombs would be thrown if you released them now. The steering cue directs you to pull up and steer left or right as necessary to stay lined up with the target; the small cross (the Apex Marker) moves up and down, left and right relative to the Aircraft Datum, the base line of the triangle is fixed and the middle horizontal line is drawn halfway between the two, skewing right or left as the Apex Marker moves. The position of the Apex Marker in relation to the Aircraft Datum tells you which way to steer - when you're pointed exactly the right way, the Apex Marker is in the exact centre of the ring of the Aircraft Datum.

Assuming that you are still well lined up on the target, the Apex Marker will be directly above the centre of the Aircraft Datum, telling you to pull straight up. If you've flown this far under AFDS control, now is the time to cancel it. Pull back firmly on the stick, and hold it back - the standard practice is to pull up at about 3.5 G. As the aircraft pitches up and starts climbing you will see the Countdown Clock run down rapidly as your bomb throw distance increases, and the Apex Marker will also move down closer to the ring centre. Both of these signs tell you that you're getting closer to the release point. You may also see the Apex Marker deflecting sideways. If it does, bank towards it to line up again, but don't overshoot on the correction. When the Clock and the Apex Marker are indicating that you're nearly at release, hold down the Commit button and let the stick come forward to the neutral centre position. At the moment of release, the HUD reverts to normal nav mode symbology and the Arm status cancels, as for any other delivery mode. *Diagram 10.10* shows a complete sequence of HUD images for a loft attack, from the start of the run through to just before release.

LOFT ATTACK from Initial Point to Release



1. At the start of the run. The target bearing is several degrees off to the right.

2. Banking right to line up on the target. Note the clock counting down to the pull-up.

3. We're now lined up, and there's still plenty of time before we reach the pull-up point.

4. Just before the pull-up, the target bearing has drifted off to the right. This gives us a better demonstarion of the "Rubber Triangle" steering cue in the next frames.

5. The symbology has changed, and it's time to start the pull-up, but we also need to make a hard right correction.

6. Chasing the Apex Marker to the right. Note the clock counting down as the bomb throw distance approaches the range to the target.

7. Steeply banked and pulling hard, we're almost lined up again, and we need to roll back towards wings-level.

8. Lined up and approaching a release solution.

9. Release is just a second or two away. Ease off on the stick to lower the pitch rate. This is the way to get maximum accuracy.

diagram 10.10

Accuracy in a Loft Attack

As with any other form of attack you must line up exactly on the target before release, but because the bombs travel so far in a loft attack any directional error will result in a miss by a correspondingly large margin. If you can see any heading error at all you must correct it before release or your bombs will be wasted.

The other great factor in loft accuracy is the pitch rate just before release. Remember that the bombs will be automatically released the instant that the throw distance is equal to or greater than the range to the target. The bombsight computer repeats its calculations for bomb throw distance at very frequent intervals, but each calculation takes time. If you are pulling up steeply, the throw distances from successive calculations go up by leaps and bounds, and the throw distance at release may overshoot the target by hundreds of feet. *Diagram 10.11A* illustrates this problem, by showing how the predicted bomb trajectory and impact point change at half-second intervals through a pull-up. You should be able to see that accuracy in these circumstances is a matter of blind luck. If instead you let the stick come forward as the release

Loft Pull-up: the Wrong Way and the Right Way

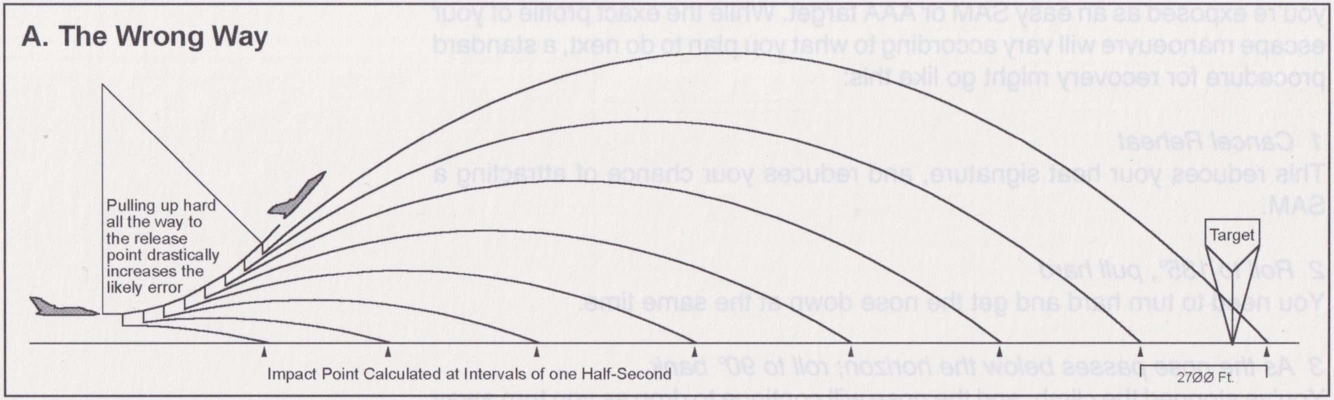


diagram 10.11A

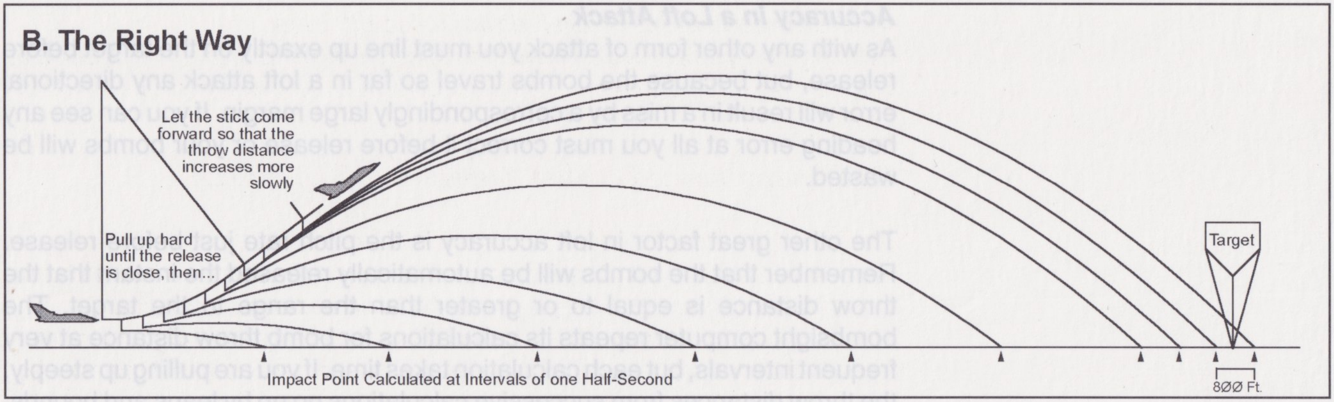


diagram 10.11B

point approaches *diagram 10-11B*, the throw distance still increases as the aircraft climbs, but it increases in much smaller steps. The resulting release will stand a far better chance of being accurate in range.

Recovery and Escape after a Loft Attack

The moment the bombs are released you're free to turn the aircraft away from the target and its defences, and you also want to avoid climbing so high that you're exposed as an easy SAM or AAA target. While the exact profile of your escape manoeuvre will vary according to what you plan to do next, a standard procedure for recovery might go like this:

1 Cancel Reheat

This reduces your heat signature, and reduces your chance of attracting a SAM.

2 Roll to 135°, pull hard

You need to turn hard and get the nose down at the same time.

3 As the nose passes below the horizon; roll to 90° bank

You've stopped the climb, and the nose will continue to drop as you turn away at the maximum possible rate.

4 As the nose passes 5° pitch down; roll to 60° bank

Pointing the nose at the ground at high speed and low level is a risky business, you need to ensure that you can pull out of your dive at a moment's notice.

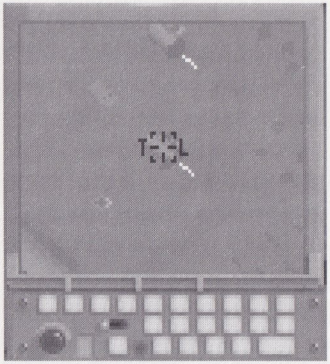
Delivering Laser-Guided Bombs (LGB on SMD)

This must be done using the TIALD system. TIALD stands for Thermal Imaging And Laser Designation. Rushed from development into service in time for the latter stages of the Gulf War, it provides TV and Imaging Infra-red cameras plus a laser designator mounted together in a swivelling 'eyeball'. In its original form this is mounted on an external pod providing services and attachment points to make the system suitable for fitting to almost any aircraft (at the 1992 Farnborough Air Show it was on display attached to a prototype Sukhoi Su-35!) but it is proposed to make the scanning head an integral installation on the Tornado GR4.

You can only laser-designate what the TIALD head under the aircraft can see, and the higher you are, the further you can see. We suggest an altitude of about 23000 feet. As with Loft attacks, a long run-in is desirable (say 6 miles or more), but we want a moderate-to-low speed (say 250 knots IAS). An LGB attack is executed entirely from the navigator's seat, with the aircraft under AFDS control.

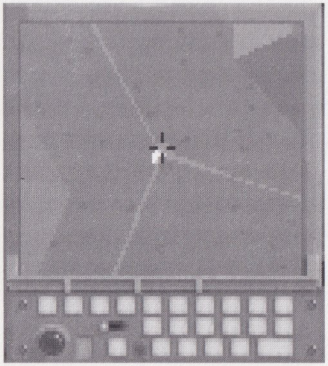
Select and commit to the Simulator Mission 'TWCU - LGB Attack'. This places you in flight at 23000 Feet, heading toward a Target Waypoint X on an airfield. Having assured yourself that the aircraft is heading in the right direction at the right speed under the AFDS, switch to the back seat. Looking at the Stores Management Display you will see that you have one package of three LGB loaded, with the Delivery mode set to LGB. Use the 'Right Tab Function Select' key to cycle through the right Tab display options till you see a downward-looking camera view (infra-red at night, visible light in daytime) with boxed crosshairs in the centre. This is the TIALD view. Check that the green light in the corner of the right Tab is on, indicating that mouse control is active on that display. If it isn't, hit the Tab key once or twice until it is on.

You will now find that moving the mouse scrolls the camera image in the corresponding direction, but there are limits to the field of view. The direction of the aircraft's movement is always up the screen, so that the image will rotate as the aircraft turns. Push the mouse forward so that you are looking at the forward edge of the camera's coverage, which is where approaching targets will first appear, and sweep the field of view from side to side. The TIALD image can be zoomed by holding down the Ctrl key and moving the mouse forward or back. When zooming, the image locks on the point at the centre of the display, compensating for the aircraft's movement, unless the trailing edge of the camera coverage catches up and pushes it forward.



TIALD Display-OK to drop

Zoom out as far as possible and move the view forward and backward between the leading and trailing edges of the available area, watching the centre symbol of the display. You should see that when the view centre is near the forward edge of coverage (ahead of the aircraft) the centre cross symbol is surrounded by square brackets, which disappear when the view is centred nearer the trailing edge (behind the aircraft). While the square brackets are shown, you could drop a bomb and continue to designate the current centre spot long enough for the bomb to reach the ground. If the square brackets are absent, the spot in the centre of the camera view would be too far behind the aircraft for you to keep it illuminated till the bomb hit.



TIALD Dispaly-too late to drop

Use a wide zoom to search for some recognisable feature in the forward half of the available camera coverage and then click the left mouse button. This locks the view and the laser designator on the point at the centre of the image, and sets the Target of Opportunity waypoint T at this point. Now zoom in closer. While you are locked on, you may finely adjust the designator spot by moving the mouse while holding down the left mouse button. It is normally best to do this in several stages, starting with a wide zoom, placing the point, zooming in closer and adjusting position, then closer for a further adjustment until you are satisfied that the laser spot is on the precise point you wish to hit. Clicking the right mouse button cancels the lock, letting the camera view roll forward over the ground at the aircraft's speed.

WEAPONS CONVERSION

Use the [D] key to cycle display options on the centre MFD till you're looking at the Local Map display (with the dotted orientation line down the centre). Hit the [O] (letter "o") key to switch the map origin (the aircraft position) from the centre of the MFD down to the bottom centre, so that you can see ahead as far as possible. As the aircraft approaches Target Waypoint X you will be able to see it marked on the map, which will help you locate it in the TIALD image.

When the target airfield starts to appear at the leading edge of the TIALD view, start zooming in to find a target - for the moment, any target will do. Don't bother to place the lock precisely for the moment, just set it somewhere in the general area of the target. Hit the arming switch and release the package immediately with the Commit button. This triggers immediate release of the first bomb. The arming status will not cancel automatically until the package is empty. This allows you to release a second and a third bomb manually at intervals of several seconds. In this way you can either make repeated attacks on one difficult target or guide each bomb in turn to a different target. An interval of four seconds between bombs is a good choice for closely spaced targets.

It will be at least 20 seconds before the first bomb reaches the ground from this altitude, and you can use this time to zoom in and refine the position of the designator spot. When you're satisfied with this, zoom out a little to give yourself a more general view. When the bomb arrives you will probably be able to see it flash into view before striking the target. If you don't change anything, a few seconds later the second bomb will strike the same spot, followed by the third.

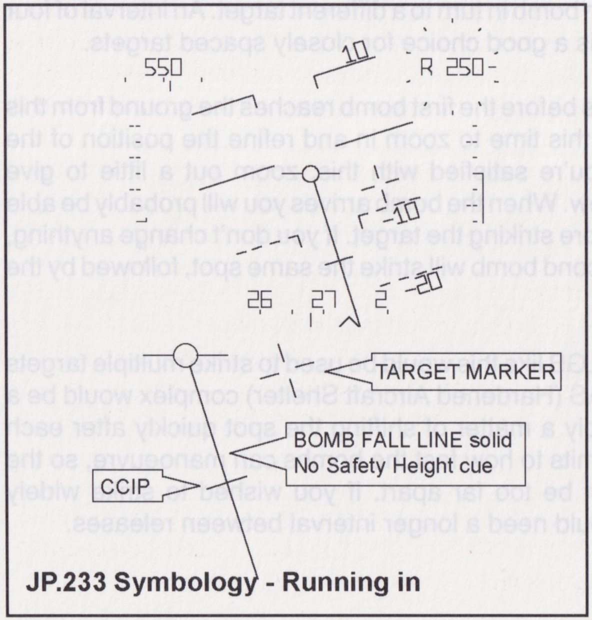
Normally a 'slow ripple' of LGB like this would be used to strike multiple targets clustered in a group - a HAS (Hardened Aircraft Shelter) complex would be a classic example. It is simply a matter of shifting the spot quickly after each bomb strikes. There are limits to how fast the bombs can manoeuvre, so the successive targets cannot be too far apart. If you wished to strike widely separated targets, you would need a longer interval between releases.

Delivering JP.233

Apart from the risks you run flying straight and level through the middle of an airfield's defences, the trickiest aspect of a JP.233 attack is ensuring that your attack run is lined up accurately to put the maximum number of craters in the desired section of runway. This should normally be catered for at the Mission Planning stage, but be aware that very accurate flying will be required to deliver the attack precisely as planned.

Select the Simulator Mission 'TWCU - JP.233' and start it up. You should be approaching the Initial Point of your attack run on Target Waypoint X at 500 knots, at 200 feet. When the aircraft starts its turn to line up on the target, hit

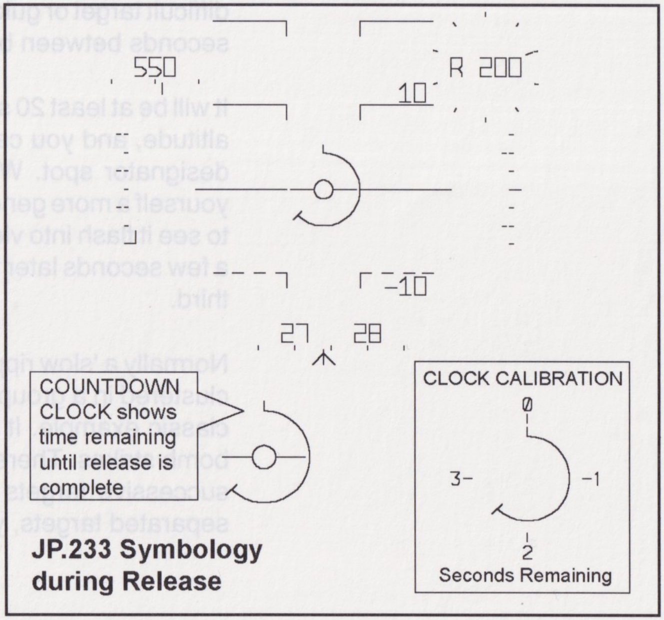
The HUD during run-in for a JP.233 Attack



JP.233 Symbology - Running in

diagram 10.12

The HUD during JP.233 Release



JP.233 Symbology during Release

diagram 10.13

the arming switch. You will see a solid Bomb Fall Line with no Safety Height cue, the Target Marker and the CCIP. As usual, the idea is to lay the Bomb Fall Line over the Target Marker - with the added complication that you must try to ensure that your course towards the Release Point matches the direction of the runway under attack. The problem is effectively identical to the problem of lining up for a landing approach, and learning to cope with either one of these problems should mean that you can handle both.

As the CCIP approaches the Target Marker, hold down the Commit button. Release starts automatically and continues till all submunitions are dispensed. Starting from the moment of release, the HUD will display a Countdown Clock. This counts down through the four seconds necessary to dispense the full load. Remember that any radical turn will spray submunitions in a wide curve. You may notice vibration and noise while the release continues.

When all submunitions are gone, the HUD reverts to nav mode and the dispenser pods are automatically jettisoned - you may notice the bump as these go. Now it's time to get the hell out of here! If you ever wanted a good excuse to fly very, very low and fast you have it now. No-one but the enemy will complain.

ALARM Attack

Hard data on ALARM is scarce and some of what there is looks deliberately misleading. The most detailed documentation we've seen describes four different operating modes, but claims that there are others still classified. We have provided for two different modes of operation which seem to us to be among the most useful of those claimed for the real missile, and modified some of the figures quoted.

ALARMS are loaded and managed in packages like all other ground-attack stores, and Direct (DIR) or Indirect (IND) mode operation is selected using the normal 'select delivery mode' key.

Launching ALARM - Direct mode (DIR on SMD)

Direct mode provides for a defensive snap shot in response to a sudden threat in front of you, the missile taking targetting information from the Radar Warning Receiver. In this mode ALARM behaves very much like a conventional anti-radiation missile such as the AGM-78 Standard ARM or AGM-88 HARM.

In order to launch an ALARM in this mode you must first select a package of ALARMs, set the delivery mode to DIR, then hit 'arm air-to-ground weapon'. The HUD symbology will change to show a Boresight Marker in place of the aircraft datum, and the ground radar emitter most directly in front of the nose (within an angle of plus or minus 45°) will automatically be designated as the target. The standard Ground Target Marker will be shown on the HUD, and a Range Clock centred on the Boresight Marker will indicate the range to this target. Maximum reading of the Range Clock is 40000 metres (130000 feet or 21.5 n.m.). If there is more than one hostile ground radar showing on the Radar Warning Receiver (RWR), swinging the aircraft nose left or right will automatically switch the designation to whichever is most directly in front.

Once the target is designated, hitting the Fire/Commit button will launch a single ALARM from the selected package on a direct trajectory. Provided that the ALARM package is not empty, the arm status will not cancel automatically on launch. If you want to disarm in order to select Indirect mode or another weapon package, you'll need to do this manually with the 'Cancel Arm' key combination. When the package is empty, however, the arming status will cancel automatically and the next package on the SMD will be selected by default. If there is no ground radar on the RWR within 45° on either side of the nose, no target will be designated and you will not be permitted to launch in Direct mode.

The HUD during ALARM Attack (either mode)

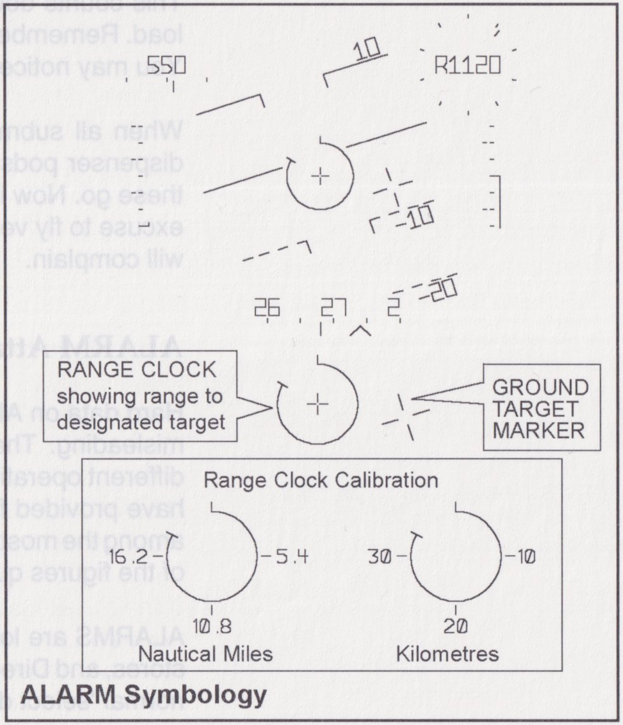


diagram 10.14

When launched in Direct mode, an ALARM will normally fly a direct trajectory to the target, accelerating to about Mach 2 while the motor burns and then coasting and slowing down. If the range is excessive and the missile's speed drops below a given threshold before it reaches the target, the missile will go into a zoom-climb to convert all its remaining speed into altitude, then deploy the parachute and scan for a target beneath, as described below for Indirect mode operation.

Launching ALARM - Indirect mode (IND on SMD)

In order to launch an ALARM in this mode you must first select a package of ALARMs, set the delivery mode to IND, then hit 'arm air-to-ground weapon'. The target will be the currently-selected waypoint, whether from the stored flightplan or a Target-of-Opportunity. The HUD symbology is identical to that provided in ALARM Direct mode, showing a Ground Target Marker and a Range Clock with the same calibration, subject to the same condition that the target must be within 45° of the nose on one side or the other.

Once the system is armed and a valid target exists, each press of the Fire/Commit button will immediately launch one ALARM at the target. The Arm status will not automatically cancel while there are still ALARMs left in the selected package.

After launch, each missile will cruise toward the target at medium altitude. Shortly before the target is reached, the missile will execute a zoom-climb to about 10000 feet and deploy its parachute. It then hangs nose-down over the target, scanning for hostile radar emission. When it finds one (or more) active radars, it will select the one most directly beneath, cut away the parachute and drop on it as a guided bomb. If no target has appeared by the time the missile has descended to 1000 feet, it will cut away and drop unguided to the ground.

If the missile is fired at a target beyond effective range, and it detects that its speed has dropped below a threshold value, it will zoom-climb and loiter wherever it happens to be at that point. If a threat radar is detected beneath, it will attack it as normal.

SAMs and AAA, Tactics for ALARM

Radar is used by SAM (Surface-to-Air Missile) launchers, and AAA (Anti-Aircraft Artillery) vehicles, both to look for targets and to direct fire, thus ALARM can be used against either - provided you can persuade or trick them into switching on.

In Tornado, we assume that only search radars are left permanently on. SAM and AAA radars will be switched on quite late as an aircraft approaches. By the time they appear on your Radar Warning Receiver (RWR) you're almost within maximum range of a SAM. While your flightplans will, of course, try to avoid known threats wherever possible, you will inevitably run across unexpected, unmapped threats from time to time. It's always sensible to assume that any target worth hitting is also worth defending, whether or not there are any known threats in the area. Defences around the planned target are an unavoidable risk.

As always, you'll have to balance risk and reward in deciding how to handle the problem. If you use Ground radar, the mobile SAM and AAA units will show up on it - but so will all other types of ground vehicle. Ground radar can't see through hills, so you're still subject to the occasional unpleasant surprise as you pass over the crest. Using Ground radar will also make you more conspicuous and easier to find, but if you know that you've already been detected or that help is available, you may consider that it's worth the extra risk.

When an unexpected threat appears on your RWR you've got to make a choice from among the following options: avoid it or face it; shoot at it or rely on defensive measures such as ECM, manoeuvre, chaff and flares. If you decide to shoot back, ALARM in Direct mode is by far the safest weapon to use. All other available weapons and modes of attack would require you to approach the target closely, flying in a more or less straight line. We'll discuss deflection shooting in detail later on, but take it on trust that it's far easier for a gun or a missile to hit an approaching (or receding) target than one which is flying past a good way off to the side.

If you want to use ALARM in Direct mode to shoot your way out of unexpected trouble, you'd better have it armed and ready so that all you have to do is hit the Fire button. In the time needed to set up a launch from a standing start you'd probably have flown straight past the threat, for better or worse. See also the section below on ECM (Electronic Counter-Measures).

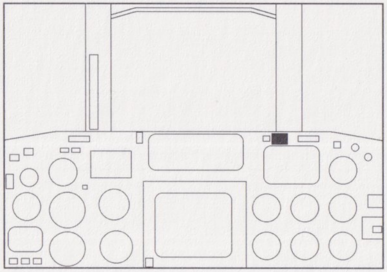
ALARM's Indirect mode is designed for use against known or suspected defences which you can't avoid. They might be the defences around your planned target, or the optimum route to or from your target might take you over a defended area. A planned attack using Indirect mode might be organised something like this: From a sensible stand-off range you fire several ALARMs, each targeted on a different point in the suspect area. We've assumed that extreme range for a launch at sea level is about 10 nautical miles (18.5 km.), and from high altitude about twice that. The missiles will reach the target area ahead of you, climb and loiter. They will not attack until a radar activates in response to an aircraft flying nearby - this could be an aircraft from either side. There's a catch here which you must understand. We've set the loiter altitude for ALARM at 10000 feet (a quarter of the published figure). If ALARM sees a target and cuts away from this altitude, it'll take about 23 seconds to reach the ground with nothing but gravity to accelerate it (ignoring air resistance, which would only make the problem worse). In that time your aircraft will cover about three miles at typical speeds, which by coincidence is roughly the maximum effective range of the SAM systems you'll encounter in Tornado. If you simply fly straight on towards the target, in all probability you'll be hit by a SAM coming the other way shortly before your ALARM lands on the launcher.

What you've got to do is launch your indirect ALARMs, then provoke the targets to switch on and activate the loitering missiles while exposing yourself to the minimum risk! You've got to enter the threat zone in order to trigger the defences, but having done so you're free to turn away. Against a heavily-defended target it's still safer than charging straight in and trying to pick off the defences with ALARMs in Direct mode.

ECM (Electronic Counter-Measures)

ECM represents a last line of defence against SAMs and AAA. It comes in many forms, but the one we're particularly interested in is intended to degrade the enemy's radar performance. If you turn on the Tornado's ECM system, SAM and AAA units will find it more difficult to obtain a lock on you, and fighter radars and missiles may also be affected. This form of ECM tries to give the enemy a false or unusable range reading by transmitting carefully timed and shaped false return signals at the threat radar.

ECM can certainly help when the enemy is shooting at you, but it is not guaranteed 100% effective. It also suffers from the same drawback as any other active system - it can attract the attention of sensors which wouldn't notice you otherwise. While it destroys the precision of range measurements, the added signal strength can actually make it easier to find your bearing. As with your radar, if you want to stay unobtrusive don't leave it on all the time. A light on the panel reminds you when it's active.



ECM ON Light

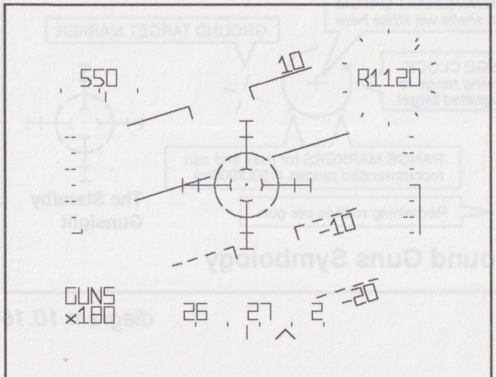
The Tornado IDS does not have a built-in ECM system - this is loaded as a pod on one of the outer wing pylons, balancing the chaff and flare dispenser on the other side. On the Mission Planner Payload Window these are collectively described as 'Defensive Pods'. The Tornado ADV has integral chaff and flare dispensers and internal ECM equipment, so this does not need to be loaded separately.

Cannon

The Tornado IDS carries two and the ADV one integral Mauser BK 27 cannon. The gun outfit of the IDS is intended for use against ground targets as well as air-to-air, and HUD symbology is provided for both uses.

Because the cannon can be used against ground or air targets we'll deal with both its applications here in the same section, and describe how to use the Air Radar mode which is essential for Air-to-Air combat.

There are in fact three HUD displays associated with the guns: one for use against a designated ground target, one for a designated air target, and one (the Standby Sight) which is the default when no target of either type is designated or within view. To use the cannon in either mode, you must start by hitting the Arm Air-to-Air key combination (Alt+Enter on most machines), and you may then cycle through the weapons available with Air-to-Air Weapon Select. You'll know when you've selected Guns because you'll see GUNS x180 in the bottom left corner of the HUD (on the ADV the Weapon status panel will also show GUNS illuminated). In addition, if you have no target currently designated, the Standby Sight will appear on the HUD. This is highly distinctive because unlike all other HUD symbology it's coloured red.



The Standby Gunsight

diagram 10.15

Guns - Standby Sight

The Standby Sight is a simple 'iron' sight, replacing the aircraft datum symbol - in other words, it makes no attempt to show you where your target is or predict its motion; its only function is to show you where your cannon shells will go. It can be used against any type of target, but only with the aid of blind luck or genius will you ever score air-to-air hits with this sight from more than a couple of hundred feet away.

It has only the virtues of its defects: it doesn't require you to switch on the radar because it doesn't use it, and you don't have to designate targets for it because it neither knows nor cares what you're shooting at.

Guns - Air-to-Ground

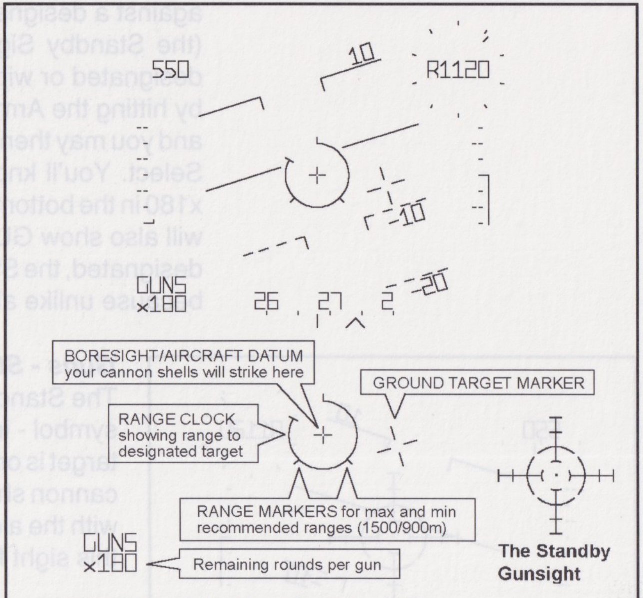
This mode is intended to help you attack Targets of Opportunity - typically groups of unarmoured or lightly-armoured vehicles, parked aircraft or other grouped soft targets. In order to use it you must set a ToO waypoint using the Scrollable Map or the Ground Radar, and select it as the current waypoint. You don't need to have the radar on, but if it is you must ensure that it's in Ground mode, not Air mode. Once these conditions are satisfied, the HUD will show the Air-to-Ground Guns symbology whenever the nose is pointed within a reasonable angle of the target. If you're pointed too far off, the Standby Sight will appear.

WEAPONS CONVERSION

The Air-to-Ground Guns symbology is quite simple and straightforward. The normal Ground Target Marker is superimposed on the target, and the aircraft datum symbol is replaced by the Boresight Marker, which should obviously be placed over the Target Marker and kept there in order to hit the target. A Range Clock is shown centred on the Boresight Marker, giving the range to the target. If the clock is showing a complete circle, the range is 2400 metres (8000 feet) or more. The two marks on the lower rim of the clock indicate recommended maximum (1500m/4900ft) and minimum (900m/3000ft) ranges.

Apart from the obvious problem of hitting the target in the first place, the main difficulty involved in using the guns to attack ground targets is due to the fact that you have to dive the aircraft at the ground in order to do it. The temptation to hang on a few seconds longer and take it a little closer is a strong one, and must be firmly resisted or you'll wind up destroying the target by crashing the aircraft on it. Quite apart from other considerations this is not cost-effective. Keep the dive shallow and pull out as soon as the range falls below the minimum recommended mark. Try it in the Simulator and you'll soon see why we make a point of this.

The HUD during an Air-to-Ground Guns Attack



Air-to-Ground Guns Symbology

diagram 10.16

Strafing practice

You can practice this kind of attack on almost any Simulator mission. The best way to find suitable targets is to use the Ground Radar. If you have enemy activity switched on (use the switches on the Mission Selection Screen) then some of these targets will shoot back at you - watch out. SAM launchers and AAA units will show up on the Radar Warning Receiver when you get within range.

Moving targets are obviously the most challenging, and for our purposes these will either be road convoys or trains. They will show up on the Ground Radar,

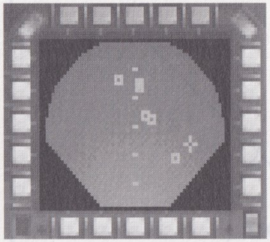
but unfortunately the designation system for ground targets won't track a moving vehicle. On the other hand, there's nothing to prevent you from setting a ToO waypoint to help you pick up the target visually.

Attacking a convoy or a train from the side is not recommended. It involves deflection shooting with no artificial aids, which is another way of saying that most of the time you'll miss. The best way to attack this sort of long thin target is with a run along its length. This minimises the deflection problem and groups all the targets together, giving you the best probability of scoring some sort of a hit. Because trucks run on roads and trains on tracks you always have two immediately obvious choices of attack run, and good visual cues for lining up. For the ideal attack you want to come in from behind rather than in front, giving you the lowest possible relative speed and the longest window of opportunity.

Having said all this, experience suggests that if you spend too long setting up the ideal attack you'll probably find that your targets turn a corner and trundle off in a new direction just before you come within range.

AIR-TO-AIR

Air Radar



MFD Air Radar Display

ENEMY AIRCRAFT

ALLIED AIRCRAFT

Air Radar Symbology

diagram 10.17

Whether you are using guns or missiles in air combat, you will need the radar switched on in Air mode to designate targets. If you don't have radar switched on you will have no indication of target range, and therefore no sighting information. You can use the guns with the Standby Sight, but you'll have to estimate deflections by eye, and you'll be unable to use missiles at all.

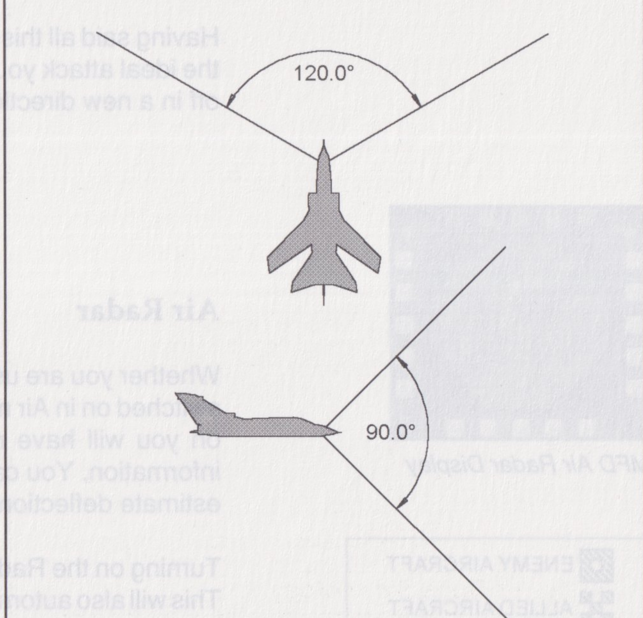
Turning on the Radar in Air mode is done by hitting Alt R on most machines. This will also automatically select the Air radar display on the MFD. The display is a plan view of the volume ahead of the aircraft nose, showing enemy and allied aircraft within range as two different types of symbol. Short-range (2n.m./

3.8km.) and medium-range (10n.m./18.5km.) displays are available in both IDS and ADV Tornados, and the ADV also offers a long-range setting (30n.m./ 55km.).

There are three different ways of designating an aircraft as a target. One is to use the mouse to point and click on the display. The second method is to point the aircraft's nose in the general direction of the enemy and hit 'boresight designate' (Caps Lock on most machines). This will select and designate the nearest aircraft in front of you. The third method is to hit 'next air target' (probably Alt+Caps Lock). If there is no air target currently designated, this will work exactly like 'boresight designate'. If there IS already a designated target, this will designate the next available candidate, so you can use it to cycle round all targets on the radar, designating each in turn.

It's important that you realise and remember that the radar can only see targets within a wedge-shaped volume in front of the aircraft. If you designate a target which then passes out of the radar's field of view, you will lose lock. If and when you re-acquire the target, you'll need to designate again. Boresight designation is the quickest and easiest method to use in close air combat - just point your nose somewhere near the target and hit the key.

The other thing to remember is that if you can see the target on your air radar, he can certainly see you on his Radar Warning Receiver. The 'radar on indicator' on the panel will help to remind you that you're still transmitting even if you replace the radar display on the MFD with another mode. If you don't need it, turn it off.



Air Radar field of view

diagram 10.18

Air-to-Air Weapon Management

Air-to-air weapons are armed with the 'arm air-to-air weapons' key. The main difference between air-to-air and air-to-ground weapon management is that you can switch between air-to-air weapons without disarming. This allows you to choose the optimum weapon for the current range and rapidly change your mind as the situation changes. In addition, all air-to-air weapon modes stay armed after firing (like ALARM or LGB), provided that you haven't run out of weapons. The normal 'Cancel Arm' key works exactly as it does in air-to-ground modes.

The HUD during an Air-to-Air Guns Attack

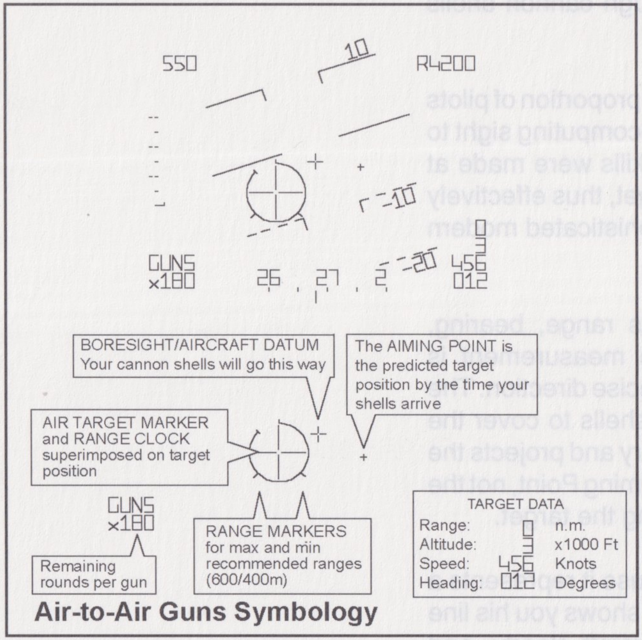


diagram 10.19

Guns - Air-to-Air

In order to use this mode: a) you must hit 'arm air-to-air weapon' (probably [Alt]+[Enter]) and select the guns using 'cycle air-to-air weapons', b) the Radar must be on and in Air-to-Air mode, c) you must have designated an aircraft as your target.

When you've designated your target a column of four numbers will appear in the lower right corner of the HUD. In order from top to bottom these show: target Range in nautical miles; target Altitude in thousands of feet; target Speed in knots and target Heading in degrees. If you want a mnemonic, think RASH for Range, Altitude, Speed, Heading. If the target is within the HUD field of view you'll see the symbology shown in *diagram 10.19*. The aircraft datum is replaced by a medium-sized cross (the boresight symbol), a large Air Target Marker cross will overlay the target, with a concentric Range Clock attached, and a small cross, the Aiming Point, will be there as well.

If the Range Clock is showing a full circle, this means that the target is at least 1000 metres (3000 feet) away. The two marks on the lower half of the clock correspond to the maximum and minimum recommended ranges, which are 600 metres (2000 feet) and 400 metres

(1300 feet) respectively. Beyond the maximum range you're very unlikely to score any hits, and if you're closer than the minimum you run the risk of hitting or ingesting debris from a damaged enemy.

The Aiming Point is the only part of this display which really needs explanation. In order to hit a target moving across your field of view, you must allow for the distance the target travels between the time you fire and the time the shot reaches the target. You have to aim ahead of the target ('lead' it) in order to have any chance of hitting it, unless it is travelling directly towards or away from you. This is the art of deflection shooting. Given that you have to aim a shotgun a metre or so ahead of a pigeon or a skeet to hit it from a range of twenty metres, you should see that when shooting at a 500-knot target from a range of 600 metres the lead distance will be considerable, even though cannon shells travel far faster than birdshot.

The history of air combat consistently shows that only a tiny proportion of pilots are capable of accurate deflection shooting without a lead-computing sight to help them. Before such sights were available, most gun kills were made at short range from almost directly ahead or astern of the target, thus effectively eliminating the need to estimate deflection. Even with sophisticated modern gunsights, there's still a lot to be said for this method.

When you designate a target, your radar measures its range, bearing, elevation and radial velocity (by Doppler effect). Each measurement is integrated with the previous ones to work out speed and precise direction. The gunsight computes how long it would take your cannon shells to cover the intervening distance, calculates how much lead is necessary and projects the Aiming Point ahead of the target. Aim the Boresight at the Aiming Point, not the Target Marker, in order to maximise your chances of hitting the target.

The Aiming Point is useful for more than just aiming. Because it represents a prediction of the target's position some time in the future, it shows you his line of flight long before you're close enough to see the aircraft clearly, and immediately signals any major course change. This information can (and must) be used to help you close the range, line up a tracking shot and react quickly and effectively to counter-manoeuvres.

Air-to-Air Missiles

Both IDS and ADV Tornados can (and usually do) carry the AIM9L Sidewinder missile for short-range air combat. The Tornado ADV carries as its main weapon payload the British Aerospace Sky Flash missile, which is for use at medium ranges, in BVR (Beyond Visual Range) combat. In the following sections we will discuss both missiles, how to launch them, and the problems involved in any missile engagement.

AIM9L (Sidewinder) missile

There can't be many of our potential users out there who haven't heard of this one. The original of this missile first went into service in 1956, but it's been upgraded so many times since that while the name is still the same and it's still a heat-seeking air-to-air missile, everything else except the body diameter has changed. Early versions were appallingly ineffective and erratic in real air combat situations, but this didn't prevent the Soviet Union from manufacturing a direct copy, the K13 (aka 'Atoll'). This copy was then copied in turn by the People's Republic of China as the PL-2. Both copies were later upgraded, but have since been replaced in front-line service by weapons of indigenous design.

Heat-seeking missiles as a class have a simple low-resolution 'eye' in the nose which 'sees' infra-red radiation rather than the visible light perceptible to you or me. Every warm object gives off an infra-red glow - this is simply radiated heat. If it's strong enough you can feel it on your skin, even though you can't see it. A properly designed infra-red seeker head is much more sensitive than this, so that even a poor one can see a glowing jet exhaust from miles away, while the best modern seekers can see the heat radiation caused by skin friction on a fast-moving aircraft from a similar distance.

Why look in the infra-red? When the first self-guided weapons were developed in the forties and fifties, compact electronic control systems were primitive or non-existent - the control systems of early weapons tended to use very simple analog electronics. Even today, with sensors, computers and software of a power and sophistication then undreamt-of, it's still a major challenge to build

a system which is capable of looking at a picture of an everyday scene and recognising even one object reliably, from any angle. What the pioneers needed was a signature of some sort - a signal that was characteristic of the sort of target they wanted to hit and really stood out from the background, so that a simple system could detect it reliably and tell whether it was coming from above, below, left, right or straight ahead. Heat and infra-red radiation offered a promising solution to this problem, since there are few things hotter than the back end of a jet engine.

A simple form of heat-seeking missile is easy to imagine. The seeker head can see very hot objects from a reasonable distance, and distinguish up from down and left from right. It takes the hottest object it can see as its target. If the target is to the left, the control system commands the missile to turn left, etc. If it's in the centre then the missile flies straight on. With any luck you would have thought it would come somewhere near its target, if it's not out of range.

In practice the problem is not that simple. You have to try to prevent the missile from locking onto the sun, the sun's reflection, and many other potential distractions, without interfering with its ability to detect and recognise the target signature. You have to provide it with some kind of proximity fuse so that it knows when to detonate.

The Sidewinder is designed to be small and light enough to be carried as defensive armament by an aircraft which is already heavily loaded with other weapons. This means that it has to be a fairly short-range missile. The only sort of propulsion which makes sense for a small missile is a small solid-fuel rocket motor - the alternatives would be prohibitively expensive, heavy and bulky. So the Sidewinder spends just a few seconds accelerating to high speed, and the rest of its short life coasting to a halt after the motor burns out.

Launching AIM9L

The following conditions are necessary to launch an AIM9L: a) you must hit the 'arm air-to-air' key combination, b) you must use the 'cycle air-to-air weapon' key to select AIM9L, c) you must turn on the radar in Air mode and designate your target, d) the missile seeker head must be able to see and lock on to the designated target.

When the target has been designated but the missile seeker cannot yet see it, the HUD symbology is as shown in *diagram 10.20*. The weapon name and the number available appear in the lower left corner, target Range, Altitude, Speed and Heading are shown in the lower right corner. The Air Target Marker and Range Clock overlay the target position. In this mode, the maximum reading on the Range Clock is 10000 metres (33000 feet). An Aiming Point is shown just as in Air-to-Air Guns mode, because it gives a useful visual indication of the target's direction of motion,

The HUD in AIM9 mode - no IR acquisition yet

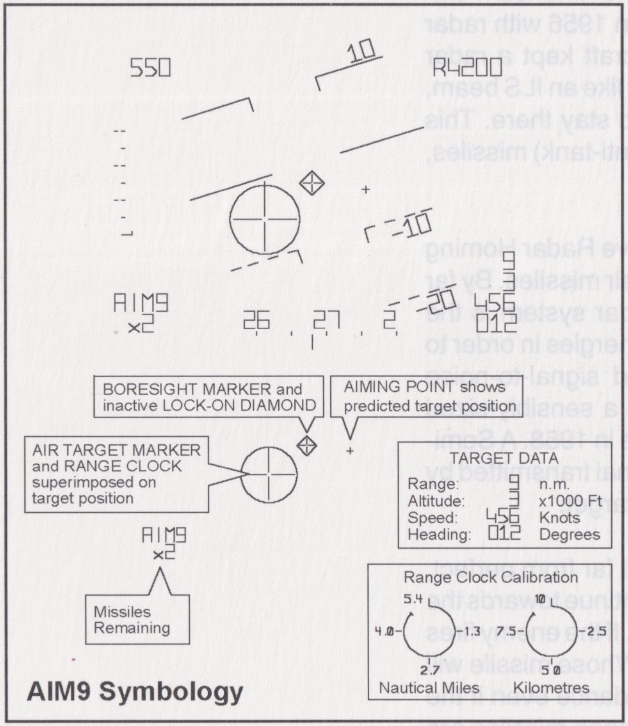


diagram 10.20

HUD in AIM9 mode after Lock-On

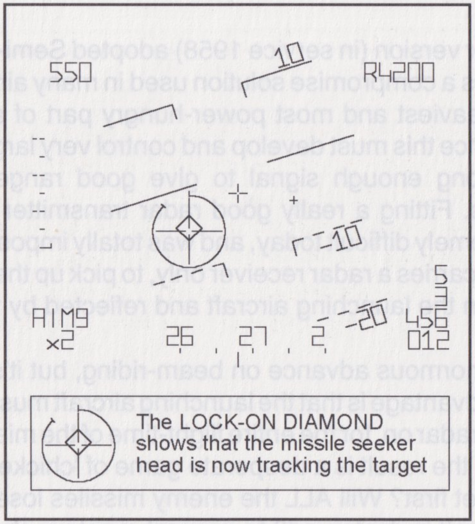


diagram 10.21

and a missile fired at close range may well not be able to hit the target unless it's launched with some degree of lead.

The other element of the symbology is the Lock-on Diamond. Until the missile seeker head acquires the target, this will rest at the centre of the HUD, surrounding the Boresight Marker. When the seeker head picks up the target and locks on, the Lock-on Diamond shifts to the Target Marker and tracks it, as shown in *diagram 10.21*. Lock-on is also confirmed by an audible signal, a steady tone.

Active Sky Flash (ADV only)

Sky Flash is a medium-range air-to-air missile derived from the American AIM-7 Sparrow. This missile entered service in its original form in 1956 with radar beam-riding guidance. This meant that the launching aircraft kept a radar beam locked on the target, and the missile treated this rather like an ILS beam, automatically steering to reach the centre of the beam and stay there. This system is still widely used for ground-launched (especially anti-tank) missiles, but it is far from ideal for an air-to-air missile.

The next major version (in service 1958) adopted Semi-Active Radar Homing (SARH). This is a compromise solution used in many air-to-air missiles. By far the largest, heaviest and most power-hungry part of a radar system is the transmitter, since this must develop and control very large energies in order to provide a strong enough signal to give good range and signal-to-noise characteristics. Fitting a really good radar transmitter into a sensibly-sized missile is extremely difficult today, and was totally impossible in 1958. A Semi-Active missile carries a radar receiver only, to pick up the signal transmitted by the big radar in the launching aircraft and reflected by the target.

SARH is an enormous advance on beam-riding, but it's still far from perfect. The main disadvantage is that the launching aircraft must continue towards the target, with its radar on, for the entire flight-time of the missile. If the enemy fires a missile back the result is a desperate game of 'chicken'. Whose missile will reach the target first? Will ALL the enemy missiles lose guidance even if the launching aircraft is destroyed? In general, western short-range missiles are

heat-seeking and medium or long-range missiles are radar-guided, but the Soviet Union made a practice of developing both radar and heat-seeking versions of almost all its air-to-air missiles, regardless of size and range class. This obviously increases the uncertainty factor.

The AIM-7 Sparrow was in its E version by the time of the Vietnam War, when it was first fired in anger. Its performance was widely regarded as unsatisfactory, though some argued that its low success rate was due to it being used at shorter ranges than it was really intended for. Over Vietnam it was usually necessary to close to visual range to be sure that the target wasn't a friendly aircraft, and if you were within visual range you were really too close for Sparrow to work as designed. The new spurt of development resulting from combat experience placed heavy emphasis on reducing the minimum range requirement.

Development of Sparrow in the USA continued into the eighties, when it was supposed to be replaced by the AIM-120 AMRAAM, but ten years later AMRAAM is still not in full-scale service and the supposedly obsolescent Sparrow is still in widespread use. Meanwhile in the UK a program began in 1969 to build the basic AIM-7E2 missile airframe under licence, but to fit it with an alternative seeker head and fuse more capable than the contemporary USA standard. The program was considered to be highly successful, and the resulting missile, christened Sky Flash, was first delivered to the RAF in 1979 and also sold to the Swedish Air Force.

Sky Flash as such is still a semi-active missile, but most of the development work has been done for a fully active version, roughly equivalent to AMRAAM. British Aerospace have been proposing such a version for years, and it's probably only financial stringency and confused political decision-making which have prevented its production. We have accordingly equipped our Tornado ADV with the proposed Active Sky Flash. At launch the fire-control system supplies an aiming point and information on the target, and the missile then steers towards that point using inertial navigation. At a preset point it turns on its own radar guidance system and uses that to home on the target without

assistance from the launching aircraft. Thus it's a real 'fire-and-forget' missile like the Sidewinder, and the pilot can manoeuvre as he likes after launch.

The HUD in SKY FLASH mode (ADV only)

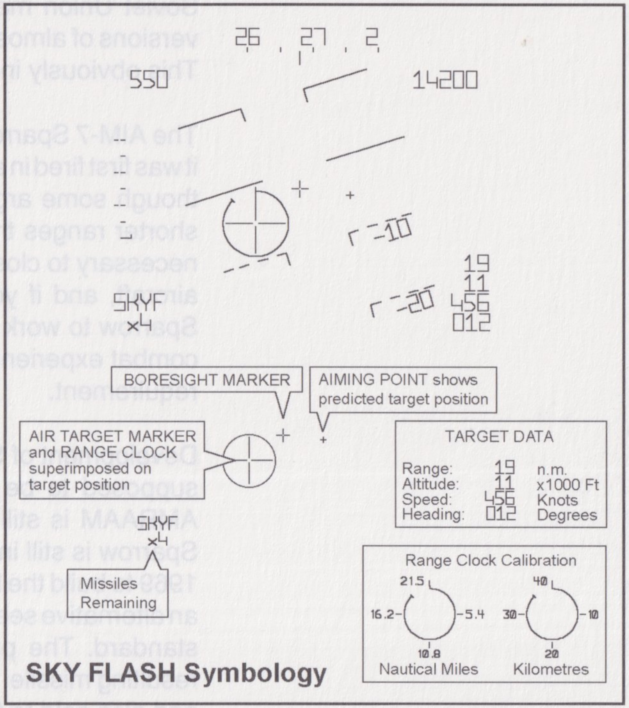


diagram 10.22

Launching Sky Flash

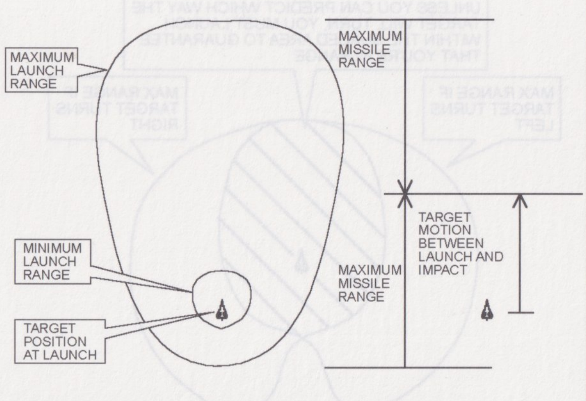
To launch a Sky Flash missile you must hit 'arm air-to-air weapon' and use 'cycle air-to-air weapon' to select Sky Flash. This will be shown in the lower left corner of the HUD, and on the Weapon Status indicator. A target must also be designated on the Air Radar, using any preferred method, and to take full advantage of Sky Flash, the radar should be set for long range. The HUD symbology is almost exactly like that provided for the AIM9L, except that there is no Lock-on Diamond, and the maximum range reading on the Range Clock is 40000 metres (130000 feet / 21.5 n.m.).

Missile Ranges

As we mentioned above, most air-to-air missiles (and all of those you'll encounter in Tornado) are powered by solid-fuel rockets which provide only a few seconds of thrust. Thereafter the missile coasts, slowing down due to air resistance, manoeuvre drag, and the direct or indirect effects of gravity. Any attempt to give a single straight answer when asked about a missile's range is bound to fail. The first uncertainty arises when you try to decide where to draw the line. Is the missile's extreme range the distance it can travel before it loses all forward momentum, or are you going to recognise that there's a speed below which it cannot manoeuvre or keep up with a given target? Among other factors affecting the range are:

Altitude

Drag is less at high altitudes, so the missile reaches a higher speed at burn-out, decelerates more slowly and travels further. Missile ranges at low altitudes tend to be disappointing, so the manufacturer will normally quote the high-altitude figure as the 'brochure range'. In practice, modern missiles may also



Missile Engagement Envelope versus Non-manoeuvering Target

diagram 10.23

Maximum Range Envelope for Target Turning Left

diagram 10.24

be launched from high-flying aircraft at low-flying targets or vice-versa, which further complicates the issue.

Target Speed and Aspect

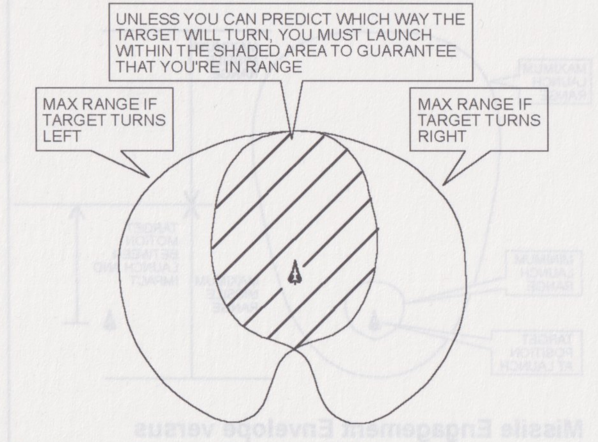
If a missile is launched head-on at an oncoming enemy aircraft, the target and the missile are travelling toward one another at high speed. The maximum launch range is greater than it would be against a stationary target, by the distance the aircraft travels in the missile's flight time.

On the other hand, if a missile is launched at a retreating target the opposite is true. Maximum launch range against a receding target is considerably less than maximum range against a stationary one, and it's easy to see that once the missile's speed has fallen below the target's a hit is impossible.

Missile theoretical engagement ranges are frequently shown by means of a diagram like *diagram 10.23*, called an engagement envelope, where the egg-shaped boundary defines maximum range from any (flat) direction relative to the target's own course. Such diagrams are helpful in that they give you an idea of relative range from different directions, but remember that the size of the boundary will change radically with altitude.

The other large assumption implicit in such a diagram is that the enemy is flying in a straight line at a constant speed throughout the attack. If he knows or suspects that there's a missile coming his way this is highly unlikely behaviour. If you assume that the target turns at a constant rate throughout the missile's flight you end up with a distorted engagement envelope something like the shape in *diagram 10.24*, where the target is assumed to be turning left. If you draw the matching envelope for a target turning right, lay it on top of

the first and shade in the area they share, this represents the area within which you can launch the missile with some reasonable hope that it can actually reach the target. As you can see, it's a LOT smaller than the first envelope we looked at - and this is still an unrealistic, idealised version of the problem.



Maximum Range Envelope if Target might turn either way

diagram 10.25

Suggested Ranges

How about some hard figures? For Sky Flash, which is normally quoted as having a 'range' of 30 miles or so, an RAF Tornado ADV pilot (interviewed in an unclassified video) has quoted launch ranges of 20 miles from ahead and 5 miles from astern. We assume that these are probably figures for fairly high altitude, against a target doing a little less than Mach 1. At low altitude, these figures might well be halved or worse.

For the AIM9L, the maximum engagement range is limited by the maximum range at which the infra-red seeker can acquire and lock the target, which we have elected to set at 8 nautical miles or so. As a rough guide, let's say that sensible maximum launch ranges at high altitude might be 5 n.m. from ahead or 1.5 from astern, or half of these figures at low altitude.

We may be doing the makers an injustice here, but if you use these ranges as a guide then at least you can be reasonably sure that the missiles will reach their targets. Whether they hit them is another question.

Missile Countermeasures: Flares, Chaff and Manoeuvres

Flares have been used to decoy heatseeking missiles for almost as long as they have existed. As we said when discussing the AIM9L, it's difficult enough to build a infra-red seeker which is immune to accidental natural distractions, let alone deliberate ones. However, modern IR seekers are a great deal more discriminating than they used to be. In some cases they can distinguish

between a brightly burning flare and a warm aircraft, or they may not be fooled for long.

Chaff - radar-reflecting strips dispensed in a cloud - has been in use against search and gunnery radar for even longer than radar-guided missiles have existed. Even though modern systems increasingly have the processing power necessary to recognise and ignore returns from chaff clouds, they may take time to reach a decision, and nothing much can be done about the actual screening effect of the cloud.

Neither of these countermeasures really gives you immunity from missiles, though they can help a lot if used properly, and in conjunction with **manoeuvre**. The basic principle is that you must use the decoy when the missile is fairly close, so that the aircraft will be out of the missile's field of view by the time the decoy has lost its effectiveness. If a missile is approaching from behind, for example, dumping decoys and continuing in a straight line may do you very little good: the missile will pass them and you will still be in view. If, on the other hand, you drop chaff and flares as the missile approaches and then turn hard or dive out of the way, you may well be more successful.

Another idea to bear in mind is turning towards the attack. This is recommended as a standard defensive move against a human fighter pilot, but it may also have applications to missile evasion at close range. The attractive point about it in either case is that it speeds up the rate at which you cross the enemy's field of view - just what you need against a temporarily-decoyed missile. The ultimate form of this manoeuvre would take you behind the missile before the decoy lost its usefulness, and the seeker head will never see you there.

All of this advice is totally useless, however, unless you know or strongly suspect that there's a missile on the way, and don't forget that the enemy will also be using all these tricks against you and your missiles.

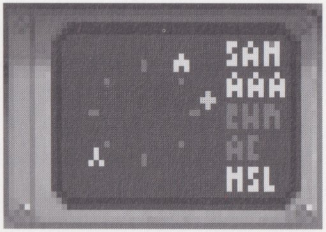
The Radar Warning Receiver (RWR)

Strictly speaking, a Radar Warning Receiver 'listens' for hostile radar signals using a system of antennae distributed all around the aircraft, identifies the type of radar and the threat it presents, and shows the result on a plan-view display. This will tell you, for example, that there's an enemy fighter behind and to your right pointing its radar in your direction, and there's a SAM launcher looking at you from the left.

The RWR we've provided on the Tornado's front panel will do these things, of course, but it has a significant extra capability. One of the features proposed for the Tornado GR4 is a Missile Approach Warning System (MAWS). Such systems (like the RWR itself) tend to be very highly classified, but there are several possible ways in which it might work, including detecting the sudden infra-red flare of a missile launching and the use of a short-range omni-directional radar with very high resolution to detect the missiles themselves.

Such a system would aim to warn you of an approaching missile, show you which direction it was coming from, and possibly even discriminate between heat-seeking and radar-guided missiles. We've assumed that all this can be done, and incorporated the result into the Radar Warning Receiver display, which thus becomes something more like a 'Threat Display', in American terminology.

The display itself shows a 'clock-face' of bearing markers on the left, and a column of text 'discretes' down the right-hand side. When a threat is detected, a symbol with a characteristic shape is placed on the clock-face at the appropriate relative bearing, and the matching text on the right will be lit up. Every time a new threat is detected, there will also be an audio warning which sounds rather like a telephone ringing. It's important to realise that the top of the clock-face displayrepresents the direction in which your aircraft's nose is currently pointing, so that a threat on your right will be shown at 3 o'clock - whichever way you're heading.



Radar Warning Receiver

Symbols for radars will be shown in green, and on the PC version at least, missile symbols are shown in two different colours; orange for radar-guided missiles and red for infra-red (or visually-guided SAMS). Check the Technical Supplement to see how missiles are distinguished on other machines.

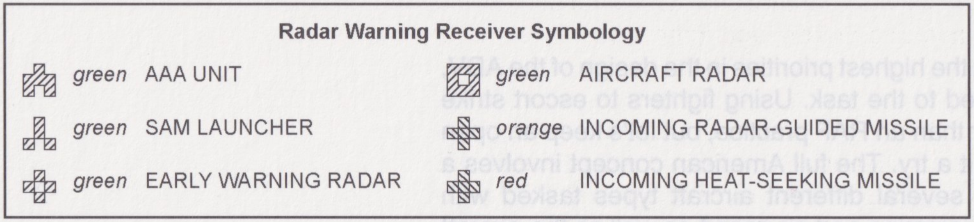


diagram 10.26

Air-to-air Tactics

As a pilot, your attitude to air combat should be entirely different depending upon the Tornado variant you're flying. Air combat is the ADV pilot's primary mission, though there will be times when it's only prudent to avoid it, and in an aircraft like the Tornado it's especially important to choose your targets and tactics carefully. If an IDS pilot becomes involved in air combat it usually means a stark choice between abandoning the primary mission or losing the fight. The Tornado is NOT the ideal dogfighting aeroplane at the best of times, and an IDS pilot who becomes involved in air combat without jettisoning ground attack weapons is at a huge disadvantage.

We'll look at the ADV pilot's particular tasks and problems before going on to look at air combat in general, as it applies to both variants.

Interception

The really important differences between ADV and IDS are the ADV's more powerful air radar and the ability to carry Sky Flash medium-range missiles. The ADV is described as an interceptor rather than an air superiority fighter. Its design role is to loiter on patrol for long periods, waiting for enemy bombers to approach, sprint to the best position for an attack and use Sky Flash to kill

from as far away as possible, as quickly as possible, with the minimum of risk. If the bombers are escorted then the tactical problem is much more difficult, but if your mission is interception it is vital to remember that you are there to knock down bombers. Defeating the escort comes nowhere in your list of priorities unless you can't get a shot at the bombers any other way.

Escort

This sort of role was not among the highest priorities in the design of the ADV, but in many ways it's well suited to the task. Using fighters to escort strike missions is an American rather than an RAF practice, but let's keep an open mind and be prepared to give it a try. The full American concept involves a 'strike package' consisting of several different aircraft types tasked with suppressing ground defences, jamming and air escort as well as the aircraft carrying the ground attack weapons. It's a huge noisy collection of aircraft which cannot hope to conceal its existence or location altogether, so it must be strong enough to fight off any likely enemy reaction.

The classic RAF concept for employing Tornados is to depend entirely on the aircraft's terrain-following ability to postpone or totally avoid radar detection until it's too late for the enemy to react by sending interceptors. The RAF has no direct equivalent of the USAF's 'Wild Weasels' (aircraft exclusively equipped and tasked for defence-suppression work), but the Tornado IDS is already quite well suited for this, and ALARM gives it a good capability. The demand for defence suppression is already less than for the 'strike package' in any case, since the route is planned to avoid known threats and the formation is a smaller, lower and more difficult target.

If you do get involved in escorting a strike mission there are many ways to deploy an escort. One way to use Tornado ADVs to protect a force of IDS might be to arrange for the escort to trail the strike formation a few miles back at low level, relying on the defence-suppression capabilities of the leading IDS to clear a path where necessary. Though the ADV has no terrain-following capability, and the pilot must work a lot harder in order to fly low safely, it shares with the IDS all the other features which make the aircraft relatively easy and

pleasant to fly at low level, and it certainly has the endurance to stay with the formation all the way if necessary.

The all-Tornado strike package is an intriguing concept. Don't dismiss it just because the RAF doesn't do it that way at the moment. Every air force evolves and uses a standard set of operating doctrines in peacetime, but the well-led ones are prepared to experiment if combat experience suggests that there might be better ways of doing things. Be prepared to try anything once, and if it works, use it.

Air Superiority

The Air Superiority mission is to drive the enemy's fighters out of the sky by engaging them directly. This is the air combat task for which the ADV is least well suited. It's optimised for long endurance and long-range missile engagements rather than seeking out the enemy's fighters and shooting them down. If possible, you should never use the ADV this way but instead rely on allied air superiority fighters to attack the enemy's fighter forces directly.

But all is not lost...

We've laid stress on the fact that a Tornado is not the world's best dogfighting aircraft because you're in for unpleasant surprises if you try to use it like an F-16. Having said that, don't get the idea that you're just a helpless flying target. A Tornado pilot goes into air combat knowing very well that if he tries to rely on brute force and superior aerodynamics he'll lose the fight against any halfway competent opponent. In order to win he's got to work out his tactics in advance and know how to make the best of his aircraft's qualities. This can be a decisive advantage against an opponent who's grown complacent because he knows he's flying one of the world's hottest fighters, as many mock combats have shown.

Close Air Combat

There's no rigid set of Commandments which will guarantee victory or even avoid defeat. All we can give you are suggestions, some of which contradict one another, but all of them contain at least a grain of truth. Some of them are intended purely for simulator pilots, and would be bad practice in the real world.

Either fight to win or run away

If you're totally preoccupied with defending yourself, you'll miss the opportunity to attack. If you miss the opportunity to attack, you can never gain the initiative. If you can't gain the initiative, you can never win the fight.

Keep your eye on the target

Especially if you're flying a simulator like this one rather than a real aircraft. Your view is unavoidably restricted, and if you once lose sight of the enemy it'll be difficult to find him again. If possible, hold him in a position on the screen where he can't quickly slip out of sight.

If the enemy is there but you can't see him, don't fly straight and level while you're looking..

Don't give your opponent an easy target. Manoeuvering will also sweep your visual and radar fields of view about, giving you a far better chance of finding your opponent. Don't forget to consult your RWR.

If in doubt, do something radical - anything!

This is related to the previous point. If whatever you're doing at the moment isn't working and you have no better ideas, a sudden unexpected manoeuvre will at least change the situation, and may gain you the advantage of surprise. Just be ready to seize any opportunity that may occur - be less surprised than the enemy.

A two-dimensional fight is a brute-force fight - you'll lose it!

The classic public conception of air combat pictures two aircraft chasing around and around in a flat circle while one aircraft tries to get on the tail of the

other. This is a bad idea on two grounds. First, a Tornado will eventually lose this sort of 'winding match' against any air superiority fighter. Second, it shows a desperate lack of imagination. Use the third dimension, Luke... If you can give the enemy a complex problem to solve, it's surely better than giving him a simple one. Remember the variants we suggested on the basic looping manoeuvre? Try them out.

Use your roll rate

The Tornado has a fairly small wing area compared with most air-superiority fighters - this is part of the reason why it can fly fast at low level. While this means that the turn performance suffers, it also confers a very fast roll rate - up to 180° per second. In this respect the Tornado is equal or superior to most fighters. Use the advantage to change your flightpath quickly.

If you've got to fight at close quarters, do it at low level..

At low level you're probably faster than the enemy and the Tornado is performing at its best. At high level, the advantages are all on his side.

Think Energy Conservation

Yes, that's right; energy conservation. This is the core concept of the theory of air combat currently taught to most fighter pilots. The energy we're talking about is the kinetic energy of the aircraft - speed times weight, which can be converted into altitude by pointing the nose up - plus its potential energy; altitude which can be converted into speed by pointing the nose down. Drag is constantly draining energy from the system and the thrust from your engines is replacing at least some of it. The biggest drain of all is manoeuvre drag, which gets worse the harder you pull. You can see speed bleed off in a hard turn - even at full Combat Power. Try to minimise this loss if you can, by not turning harder than you're forced to. If you run out of airspeed and altitude at the same time, you're in deep trouble. If you're bleeding energy and can't recover it, you might do better to try to break off and run away while you can; you're about to run out of options.

Don't overshoot your target from behind
If you do, you're giving him a very easy shot.

If the enemy is close behind, try to make him overshoot
See the above.

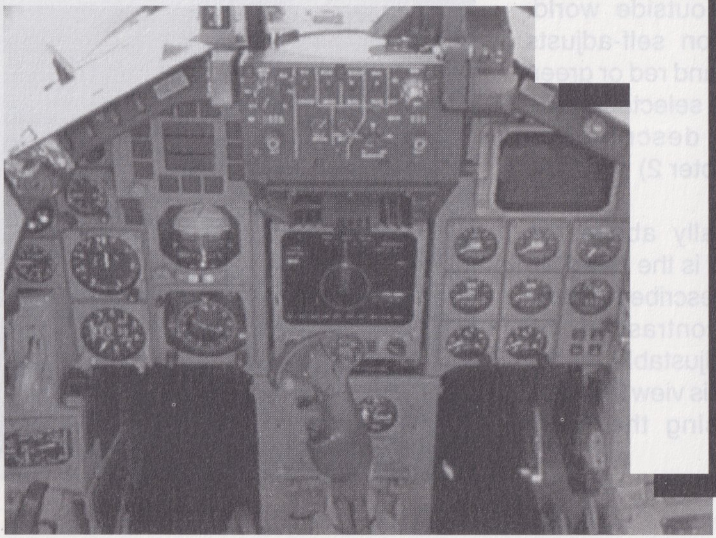
A slow-moving aircraft has a smaller turning circle than a fast-moving one..
This is one excellent reason why air combat normally takes place at moderate speeds (say 400 - 500 knots). Simplifying slightly, we can say that turning performance is described by two factors. One is speed, as described. The other is RATE of turn; how many degrees the aircraft turns per second, which is mainly governed by how much G is pulled in the turn. If you experiment, you'll find that the Tornado's maximum 7.5 G just isn't available below a speed somewhere in the region of 400 knots. Flying faster than this doesn't give you any greater G capability, because it's a structural limit of the aircraft. If you fly faster, all that will happen is that your turning circle becomes larger.

At the minimum speed which allows you to pull 7.5 G the aircraft's turn rate is at its maximum and its turning circle is at its smallest for that rate. This is called the Corner Speed, and it's good practice to try to stay somewhere near this speed for combat manoeuvering. Unfortunately, the Tornado's engines are not powerful enough to make up for the manoeuvre drag at 7.5 G, so maximum turn performance is only available in a diving turn.

The other side of this particular coin is that a aircraft with a moderate G limit flying slowly can sometimes out-turn an aircraft with a high G limit flying faster.

AIRCREW NOTES

CHAPTER



AIRCREW NOTES

COCKPIT LAYOUT

Pilot's seat

Views available

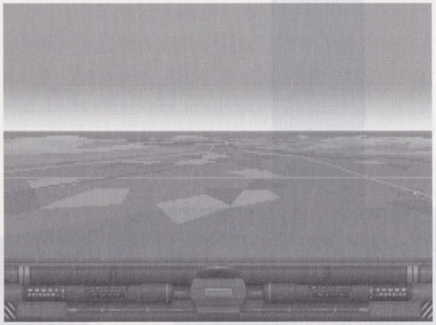
This is the view looking forward from the pilot's position (front cockpit). The lower portion of the screen is occupied by the instrument panel and above this you are looking through the canopy to the outside world. Panel illumination self-adjusts with time of day and red or green cockpit lighting is selectable (see "Preferences" described in "Options" in chapter 2)

Mounted centrally above the instrument panel is the Head Up Display (HUD), described in detail later. Clarity/contrast of the symbology is adjustable by the pilot. Return to this view from any other by pressing the Front Cockpit key.

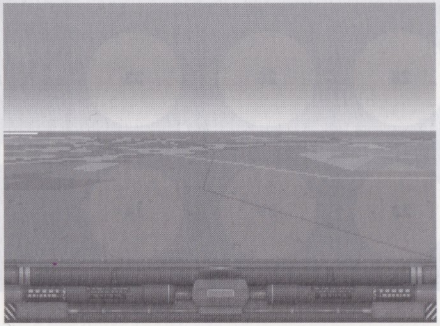
Forward View


Forward and Up View

Pressing the Front Cockpit key when already in the front cockpit will select the "forward and up" view. The upper portion of the canopy framework will be visible.

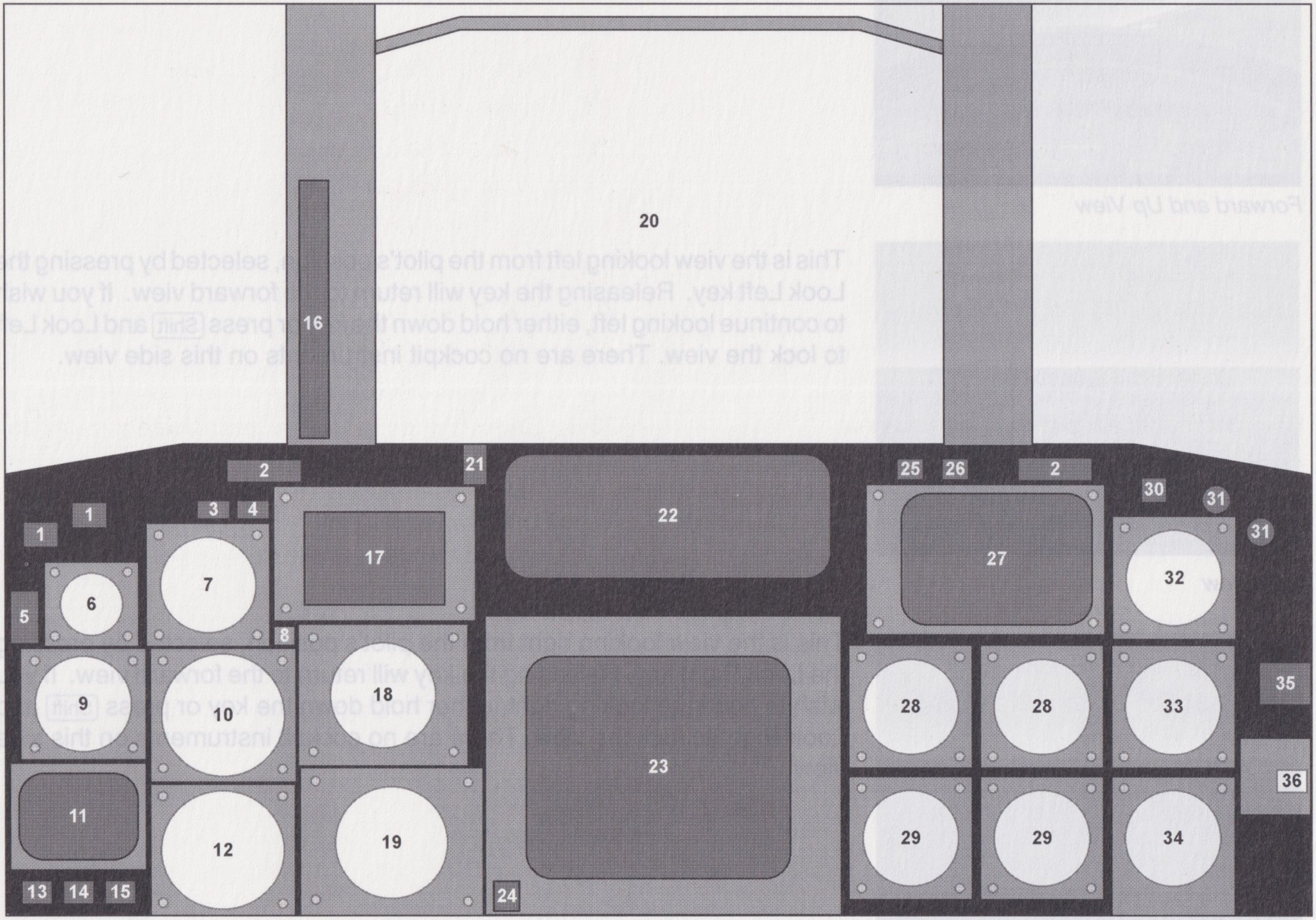

Left View

This is the view looking left from the pilot's position, selected by pressing the Look Left key. Releasing the key will return to the forward view. If you wish to continue looking left, either hold down the key or press Shift and Look Left to lock the view. There are no cockpit instruments on this side view.


Right View

This is the view looking right from the pilot's position, selected by pressing the Look Right key. Releasing the key will return to the forward view. If you wish to continue looking right, either hold down the key or press Shift and Look Right to lock the view. There are no cockpit instruments on this side view.

Instruments



Pilot's Instrument Panel

Key

1	Reverse thrust indicators
2	Attention getter
3	Autopilot engaged indicator
4	Autothrottle engaged indicator
5	Wheel brakes
6	Landing gear position indicator
7	Radar altimeter
8	"B" risk indicator
9	Vertical speed indicator (VSI)
10	Indicated airspeed / Mach number
11	Secondary control surfaces position indicator
12	Altimeter
13	Jettison all external stores + internal fuel
14	Jettison all external stores except AIM9-L
15	Jettison external fuel tanks
16	Angle of attack indicator
17	E-Scope (IDS) or weapon status (ADV)
18	Horizontal situation indicator (HSI)
19	Attitude direction indicator (ADI)
20	Head up display (HUD)
21	Late arm switch
22	Head up display control panel
23	Multi-function display (MFD)
24	Mouse active indicator
25	Radar "on" indicator
26	ECM "on" indicator
27	Radar warning receiver
28	Engine r.p.m. indicators (left & right)
29	Engine temperature indicators (left & right)
30	Approach progress indicator
31	Reheat operating lights
32	G meter
33	Fuel flow indicator
34	Fuel quantity indicator
35	Standby compass
36	Oxygen flow indicator

Reverse thrust indicators
Illuminated when reverse thrust selected.

Autopilot engaged indicator
Illuminated when autopilot (AFDS) engaged.

Autothrottle engaged indicator
Illuminated when autothrottle engaged.

Attention getter
Illuminates after system failure or warning. Refer to Central Warning Panel in rear cockpit for identification of problem.

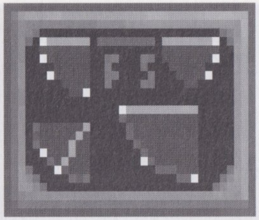
Angle of attack indicator
Mechanical display of angle of attack.

Head up display
See separate section later.

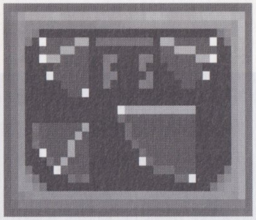
Late arm switch
Moves to its upper (armed) position after weapons armed using “arm ground attack” key or “arm air attack” key. Moves to its lower (disarmed) position by using “cancel arm” key. Weapons cannot be fired when the Late Arm switch is down.

“B” risk indicator (IDS only)
Warning light advising you that Terrain Following system is at risk of being unable to maintain the required safety margin. Usually caused by attempting to fly too fast at low altitude. Recommended action is to reduce speed or increase your ride height. n.b.This indicator operates only when the autpilot is in Terrain Following mode.

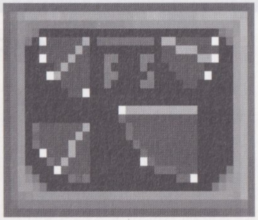
Wheel brakes
Illuminated when wheel brakes applied.



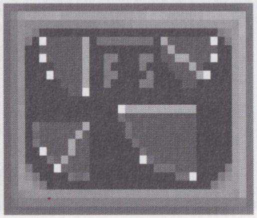
Zero Flaps



Manoeuvre Flaps



Mid Flaps



Full Flaps

Radar "on" indicator
Illuminated when aircraft's radar is active. Serves as a reminder to aircrew that the radar is transmitting even though it may not be selected on the MFD.

ECM "on" indicator
Illuminated when aircraft's ECM is active. Serves as a reminder to aircrew that the ECM equipment is transmitting.

Approach progress indicator
Illuminates during the approach to an allied airfield, 3500 feet from the runway threshold. This serves as a reminder that touchdown is imminent.

Reheat operating lights
Illuminate when engine reheat selected.

Landing gear position indicator
(a) Three green lights - gear down and locked
(b) Three red lights - gear not locked up or down
(c) No lights - gear locked up

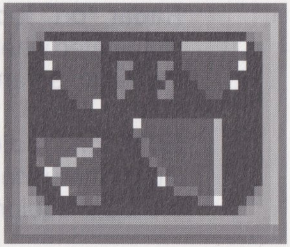
Vertical speed indicator
Moves clockwise for a positive rate of climb and counter-clockwise for a negative rate of climb (i.e. descent).

Secondary control surfaces position indicator

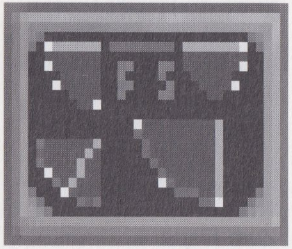
(a) Upper left - four flap positions:	zero flap
	manoeuvre flap
	mid flap
	full flap
(b) Upper right - slat positions:	zero slat
	manoeuvre slat
	mid slat

n.b. slat and flap positions are linked and not separately controllable

(c) Lower left - airbrake position

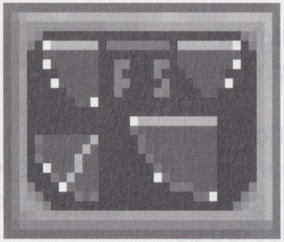


Airbrake on

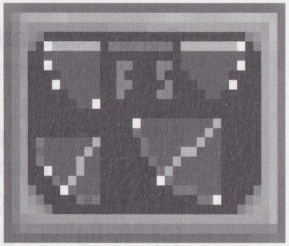


Airbrake off

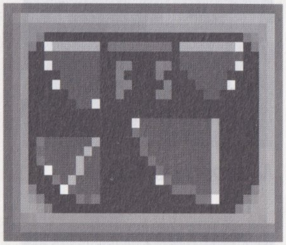
(d) Lower right - wing sweep:



25° sweep



45° sweep



67° sweep

Jettison indicators

Three lights to confirm successful jettison of:

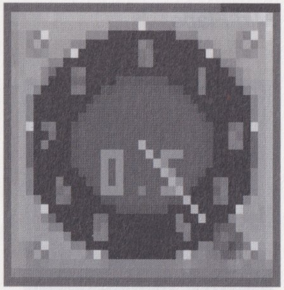
Left:	all external stores plus internal fuel to minimum
Centre:	all external stores except AIM9-L
Right:	external fuel tanks

Radar altimeter

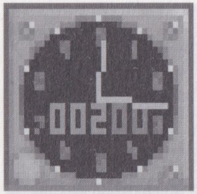
Indicates height above ground level when below 5000 feet barometric. Non-linear scale with highest resolution at low altitude.

Indicated Airspeed / Mach number

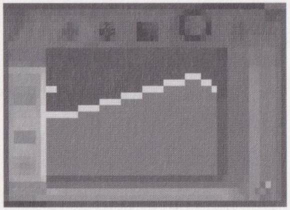
Analogue dial showing Indicated Airspeed up to 800 knots and digital readout of Mach number.



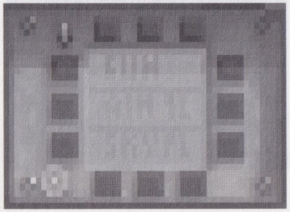
IAS/Mach number



Altimeter



E-scope on IDS

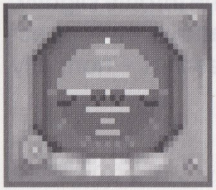


Weapon Status on ADV

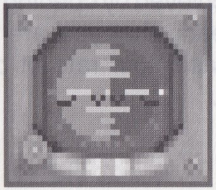
Altimeter
Analogue dial showing barometric altitude. Each revolution of the large needle represents 1000 feet. Each revolution of the small needle represents 10000 feet. Also incorporates a numeric display for those who prefer a digital presentation.

E-scope (IDS) or Weapon status (ADV)
(a) E-scope (IDS Tornado)
Shows projection of terrain ahead of aircraft when flying at low altitudes. Distance of "look-ahead" is automatically adjusted to increase with aircraft speed. The small marker on the left edge of the display represents your aircraft.
(b) Weapon status (ADV Tornado)
The weapons status indicator shows which air-to-air weapon is selected (highlighted) and armed (flashing). The pilot may select between guns, AIM9-L Sidewinder or Sky Flash. The weapon name will not highlight if it is not available.

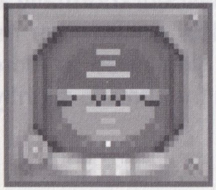
Attitude direction indicator
Otherwise known as an artificial horizon, this instrument shows the pitch and roll attitude of your aircraft relative to the ground. For example, pitch up and the artificial horizon will fall, roll right and the artificial horizon rolls left. A small "bug" travels around the circumference of this instrument showing your roll orientation. This is particularly useful when your aircraft is pitched so far up or down that the horizon is no longer visible.



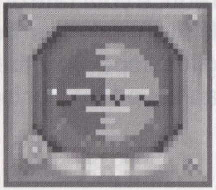
Level Flight



Rolled 90° right



Flying Inverted



Rolled 90° left

Horizontal situation indicator (HSI)

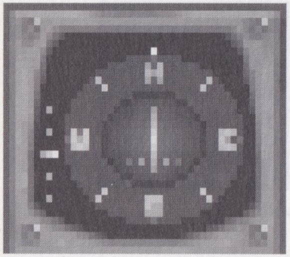
This instrument has two functions:

Firstly, it indicates your aircraft's heading by means of a "bug" travelling around the circumference of the compass rose.

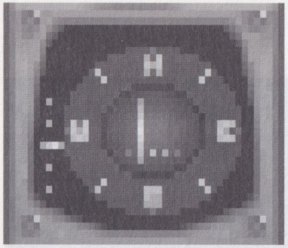
examples:	bug at 12 o'clock	heading due North
	bug at 3 o'clock	heading due East
	bug at 6 o'clock	heading due South
	bug at 9 o'clock	heading due West

Secondly, it is part of the Instrument Landing System and shows localiser and glideslope deviation during an approach to an allied airfield. However, it is strongly recommended that you use the ILS mode of the HUD or the ILS mode of the MFD in preference to this instrument under normal circumstances. The limitations in resolution on the HSI make it a difficult instrument to use but in the event of simultaneous HUD and MFD failure it is a useful "last resort".

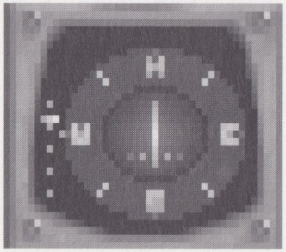
The vertical needle is linked to the runway localiser and shows deviation from the runway centreline. If the needle is to the left of centre, this indicates that the runway centreline is to the left of your aircraft and that you should adjust your heading by turning left a few degrees. As the needle returns to centre, adjust your heading by turning right until you are aligned with the runway. Likewise, turn right if the needle is displaced to the right. A small vertical scale can be seen on the left of the instrument and this may be used to follow the correct glideslope down to the runway threshold. If the marker is above centre, this means that you are below the correct glideslope and that you need to reduce your rate of descent - normally achieved by opening the throttle slightly. If the marker is below centre, this means that you are above the correct glideslope and that you need to increase your rate of descent - normally achieved by closing the throttle slightly.



Bug at 12 o'clock flying north

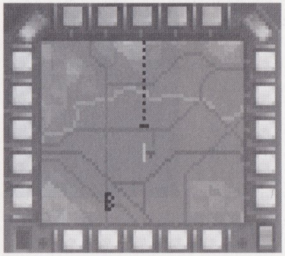


Runway to your left



Below Glideslope

AIRCREW NOTES



Multi Function Display

Multi Function Display (MFD)

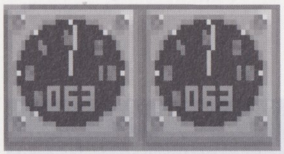
Mounted centrally on the instrument panel of both pilot and navigator you will see the Multi Function Display, a distinguishing feature of the GR4 Tornado. This unit offers a variety of functions, selected by the "Centre MFD Function Select" key.

- Autopilot and Flight Director System (AFDS) plus Autothrottle - if active
- Local map
- ILS
- Ground radar - if active
- Air radar - if active
- Forward looking camera

All of these are described in detail in the Avionics Reference section. It is possible to switch off the MFD by pressing the MFD On/Off key. The buttons surrounding the MFD are not functional.

Mouse active indicator

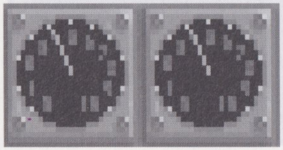
When mouse control is appropriate to more than one current display e.g. with the radar on the MFD and the moving map on a TV TAB display, control may be passed between the displays by use of the "Select active display" key. The indicator will illuminate to confirm mouse control is active.



Engine r.p.m. Indicators

Engine rpm indicators

Individual analogue rpm indicator for each engine (left and right). Normally shows 63% at engine idle. Full scale deflection of 100% at maximum dry thrust (no reheat) and throughout all reheat settings.



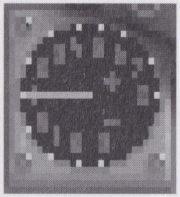
Engine Temperature Indicators

Engine temperature indicators

Individual analogue temperature indicator for each engine (left and right). Normal reading of 400°C at idle and 700°C at full reheat. Higher than this probably means that you are on fire.....

G meter

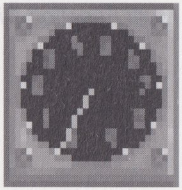
Shows g force due to aircraft manoeuvres. For straight and level flight the reading will be 1g with the pointer at the 9 o'clock position. Maximum positive g force of 7.5, maximum negative g force of -3.



G Meter

Fuel flow indicator

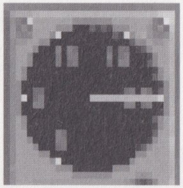
Very little movement is evident on this instrument unless reheat is selected. This instrument is then particularly useful for assessing the extent of reheat in use. n.b. Fuel flow for any given throttle setting decreases as your altitude increases.



Fuel Flow Indicator

Fuel quantity indicator

Shows total quantity of fuel remaining. Fuel in external tanks is represented by the red-bordered sector from 12 to 3 o'clock on the gauge.



Fuel Quantity Indicator

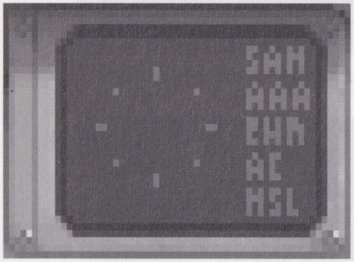
Standby compass

Shows magnetic compass heading of aircraft.

Radar warning receiver

This display shows when your aircraft is being tracked by enemy radar, both ground-based (e.g. SAM or AAA) and airborne (e.g. fighter aircraft). The display also shows incoming ground-launched or air-launched missiles, both infra-red and radar-guided. Discretes on the right of the display will illuminate as follows:

SAM you are being tracked by a SAM launcher
AAA you are being tracked by anti-aircraft artillery
EWR you are being tracked by ground-based early warning radar
AC you are being tracked by an enemy aircraft
MSL incoming missile, infra-red or radar-guided, ground or air-launched

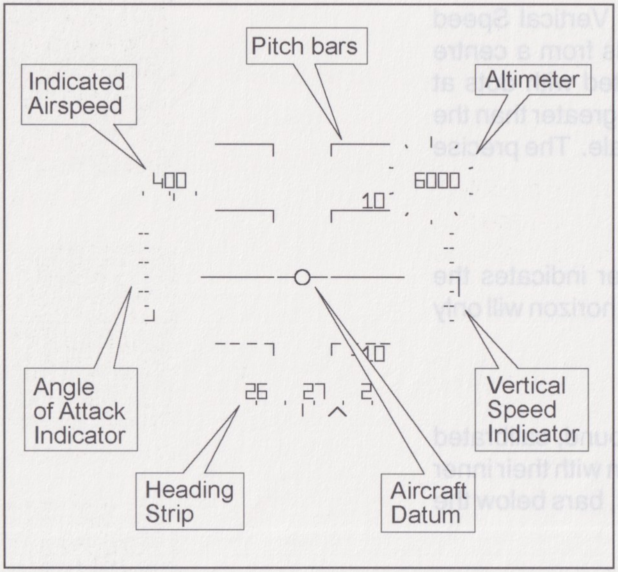


Radar Warning Receiver

Radar Warning Receiver Symbology

green	AAA UNIT	*green*	AIRCRAFT RADAR
green	SAM LAUNCHER	*orange*	INCOMING RADAR-GUIDED MISSILE
green	EARLY WARNING RADAR	*red*	INCOMING HEAT-SEEKING MISSILE

The HUD in NAV Mode (IDS)



HUD symbology

Symbology on the HUD will vary depending upon the mode in use. Without weapons armed, the HUD defaults to NAV mode.

Indicated airspeed or Mach number

Digital readout of Indicated Airspeed (IAS) in knots or Mach number.

Time early/late

Three graduations and a marker found immediately below the speed readout. The marker will drift left or right of centre to indicate arrival at next waypoint up to thirty seconds late or early respectively. If time of arrival differs from plan by more than thirty seconds then the marker will remain at full scale deflection. This symbology only appears if you are flying in the general direction of a timed waypoint, thus permitting a meaningful calculation of time of arrival.

Angle of attack (Alpha)

A vertical strip meter on the left hand side of the HUD, calibrated by single and double dots, each representing 5° of alpha. Maximum alpha for any wing sweep is approximately 21° and beyond this, your aircraft will stall.

Altitude

Height of own aircraft above sea level (barometric altitude) or height of own aircraft above ground level (radar altitude), both measured in feet. Whenever you fly within 5000 ft of the ground, the readout will switch automatically from "barometric" to "radar" signified by the symbol "R". When below 5000 feet the readout will vary as you fly over hills. "T" will appear beneath the readout whenever Terrain Following is active.

Altitude clock

Circular graduations around the digital altitude readout calibrated in units of 100 feet. One full "revolution" of the marker represents 1000 feet.

Vertical speed
Half-way up on the right hand side of the HUD is the VSI - Vertical Speed Indicator. This is shown as a vertical bar which rises or falls from a centre position as the aircraft climbs or dives. Its scale is calibrated with dots at intervals of 5 feet per second. If the rate of climb or descent is greater than the scale allows (and it often is), the bar sticks at the end of the scale. The precise rate of climb or descent is most useful during landing.

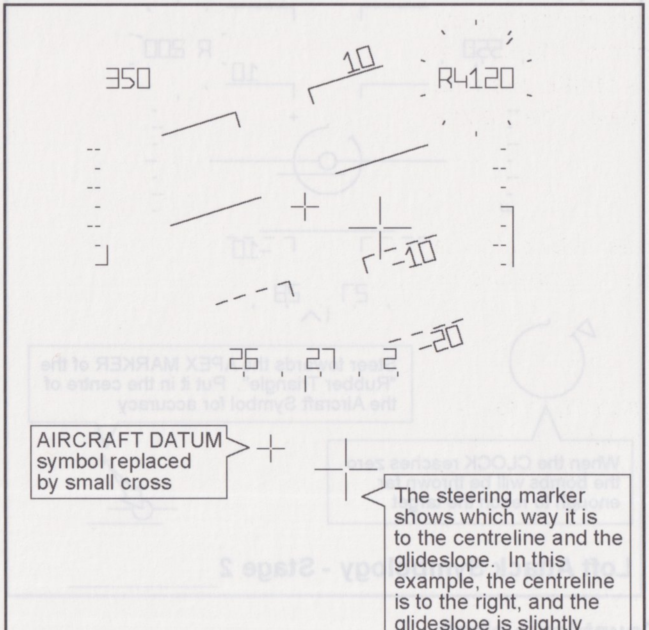
Aircraft datum
The position of this symbol relative to the HUD pitch ladder indicates the aircraft's attitude i.e. nose up or down. n.b. Alignment with the horizon will only correspond to level flight at higher speeds.

Pitch ladder
Bars showing aircraft pitch and roll attitude relative to the ground, calibrated every 10°. The bars will always remain parallel with the horizon with their inner ends pointing at the ground. Bars above the horizon are solid, bars below the horizon are broken.

Heading strip
Aircraft compass heading across the bottom of the HUD, calibrated in units of 10° (e.g. 270 is shown as 27), calibrated every 5° with a resolution of 1°. A heading of 36 corresponds to your aircraft flying due North (360°).

Waypoint bearing
An inverted V on the heading strip showing the required aircraft heading in order to fly directly towards the selected waypoint. If the required heading is off scale, the V will remain at full deflection on the appropriate side of the heading strip.

The HUD in ILS mode

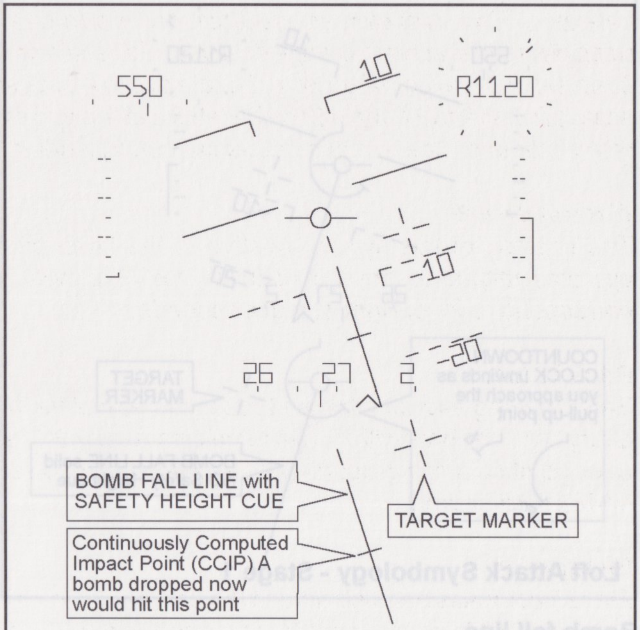


HUD ILS Symbology

ILS steering marker

The steering marker is linked to the runway localiser and glideslope ILS transmitters. If you are aligned with the runway centreline and following the required glideslope, the steering marker will overlay the aircraft datum symbol in the centre of the HUD. If the marker is off centre, steer towards it.

The HUD in Laydown Bombing Mode



Laydown Bombing Symbology

Bomb fall line

Line along which the bomb will fall after release. Safety height cue gives indication of safety margin so that pilot may avoid flying through debris hemisphere of exploding weapon.

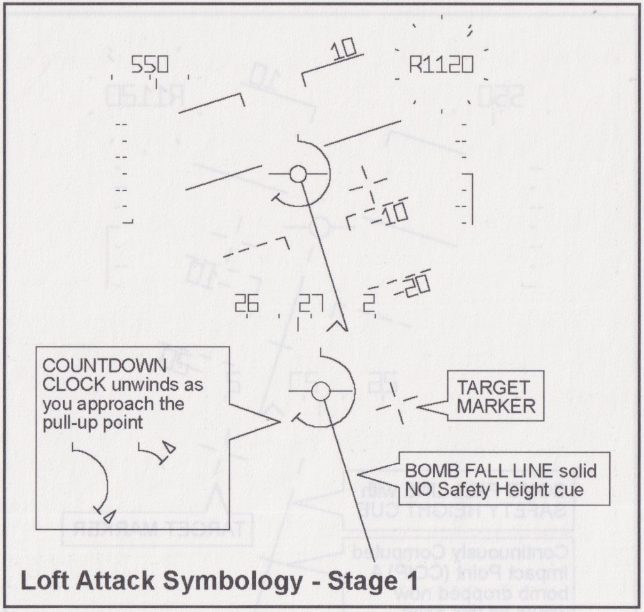
Continuously computed impact point (CCIP)

Marker across the bomb fall line showing the bomb's computed impact point if released immediately.

Ground target marker

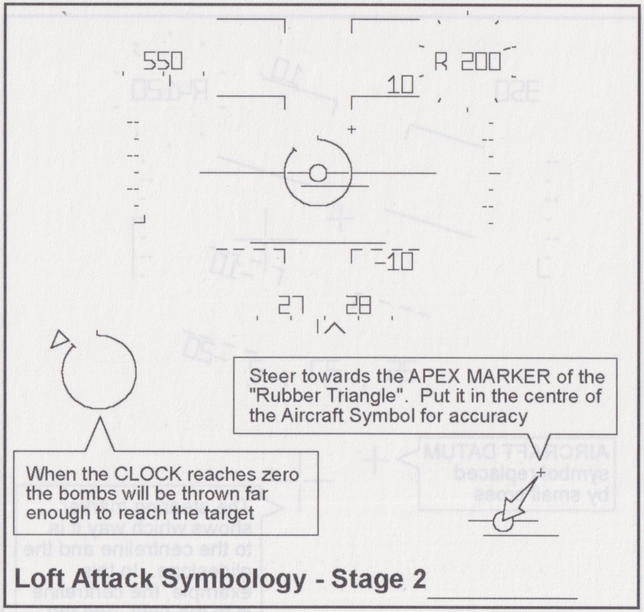
Position of designated target as seen through the HUD.

The HUD during run-in for a Loft Attack



Loft Attack Symbology - Stage 1

The HUD during a Loft Attack Pull-up



Loft Attack Symbology - Stage 2

Bomb fall line
Line along which the bomb will fall after release.

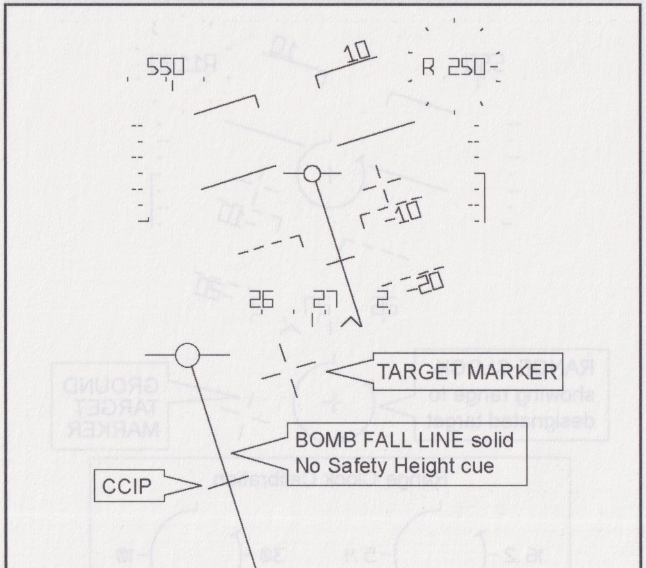
Countdown clock
Counts down to the “pull up point” and the start of stage 2.

Ground target marker
Position of designated target as seen through the HUD.

Countdown clock
Shows the difference between the range to the target and the distance your bombs would be thrown if you released them immediately. Unwinds as your aircraft approaches weapon release. Calibration dependent upon weapon type.

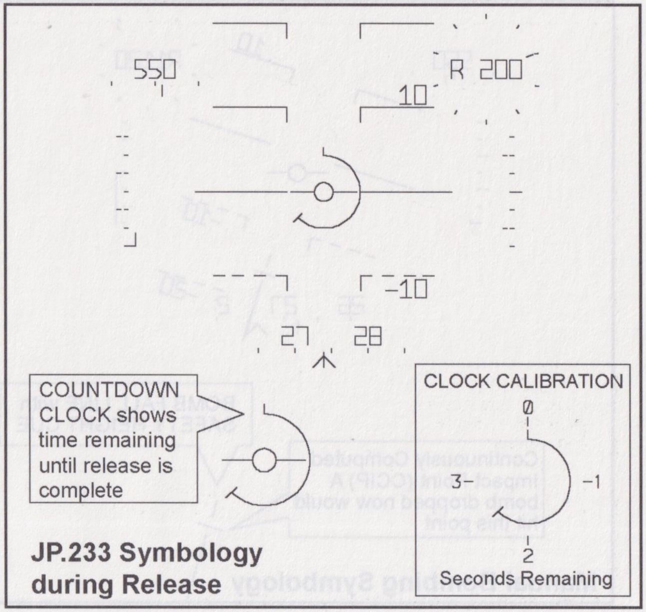
Rubber triangle
A steering cue consisting of an apex point (small +), a short middle line and a long base line. The position of the base line is fixed. The apex marker moves left,right,up and down relative to the aircraft datum to indicate a steering demand to the pilot. The middle line is drawn half way between the apex marker and the base line and moves left and right.

The HUD during run-in for a JP.233 Attack



JP.233 Symbology - Running in

The HUD during JP.233 Release



JP.233 Symbology during Release

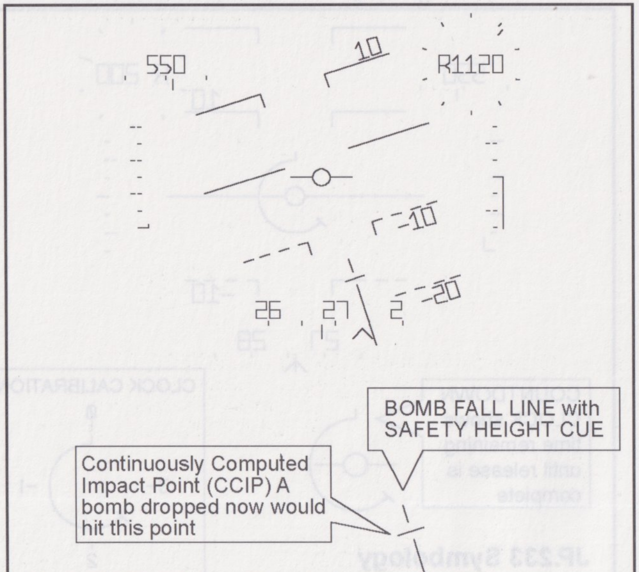
Bomb fall line
Line along which the bomb will fall after release.

Continuously computed impact point (CCIP)
Marker across the bomb fall line showing the bomb's computed impact point if released immediately.

Ground target marker
Position of designated target as seen through the HUD.

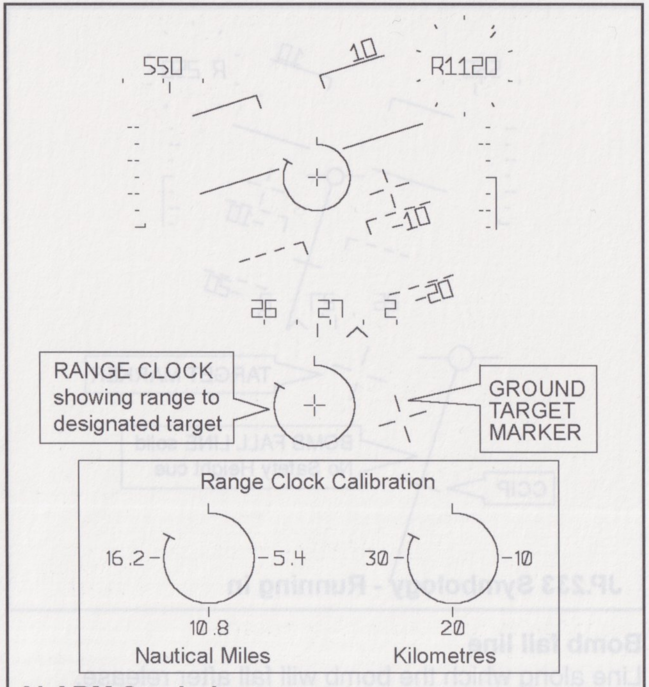
Countdown clock
Appears when the CCIP reaches the target marker. Counts down through the four seconds necessary to dispense the full weapon load.

The HUD in Manual Bombing Mode



Manual Bombing Symbology

The HUD during ALARM Attack (either mode)



ALARM Symbology

Bomb fall line
Line along which the bomb will fall after release. Safety height cue gives indication of safety margin so that pilot may avoid flying through debris hemisphere of exploding weapon.

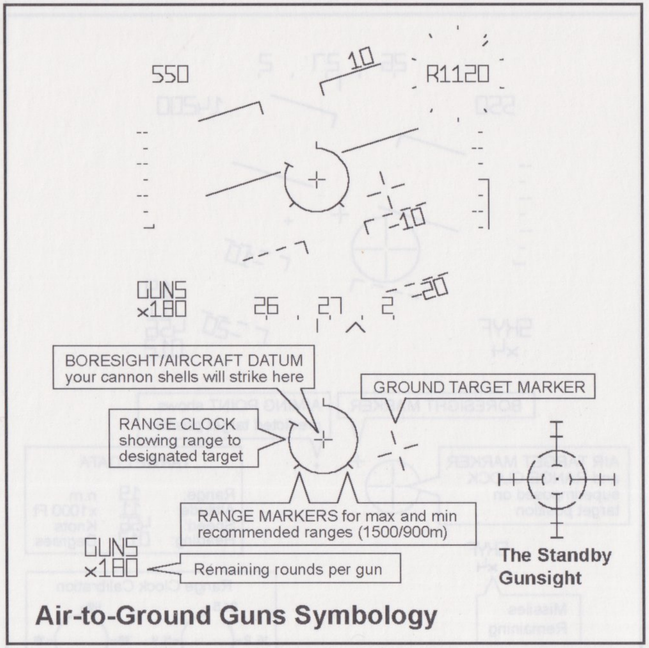
Continuously computed impact point (CCIP)
Marker across the bomb fall line showing the bomb's computed impact point if released immediately.

Boresight
This replaces the aircraft datum.

Range clock
Displays range to target with maximum range of 21.5 nm (40 km)

Ground target marker
Position of designated target as seen through the HUD.

The HUD during an Air-to-Ground Guns Attack



Air-to-Ground Guns Symbology

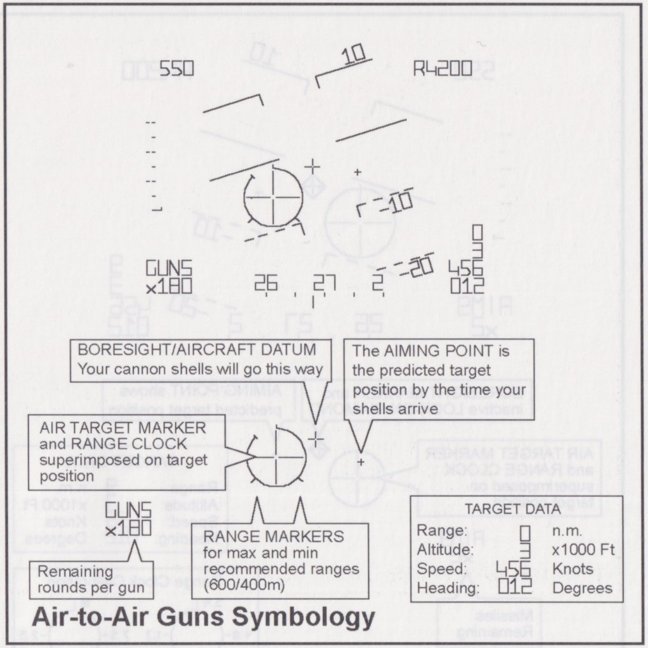
This mode is only available with a target of opportunity selected as the current waypoint.

Boresight
Direction in which your cannon shells will travel if fired now. This replaces the aircraft datum.

Range clock
Displays range to target with two calibration marks: 900m and 1500m range

Standby sight
Larger red sight which appears when cannon armed but no target is designated.

The HUD during an Air-to-Air Guns Attack



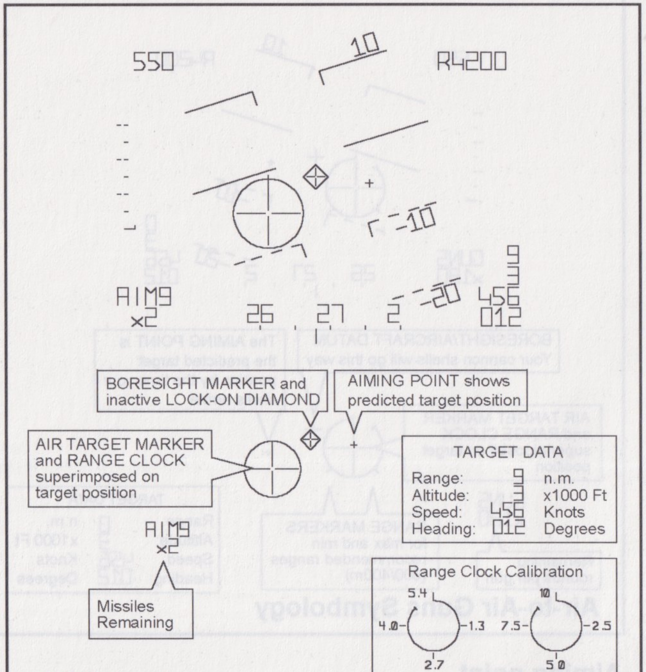
Air-to-Air Guns Symbology

Aiming point
Prediction of the target's position. Manoeuvre your aircraft so that the aiming point coincides with the boresight and fire your cannon when in range.

Air target marker
Position of air target projected onto HUD display.

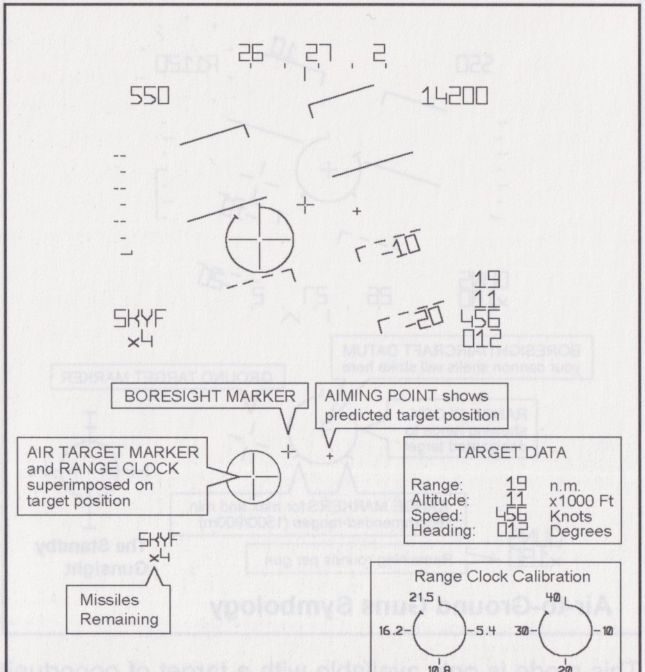
Range clock
Displays range to target with two calibration marks: 400m and 600m range

The HUD in AIM9 mode - no IR acquisition yet



AIM9 Symbology

The HUD in SKY FLASH mode (ADV only)



SKY FLASH Symbology

IR Lock diamond
When the missile's IR seeker has acquired the target this symbol moves from the centre of the HUD to the target marker.

Range clock
Shows range to target, calibrated for AIM9-L.

Aiming point
Prediction of the target's position. May be used as a steering cue.

Mode is similar to AIM9-L symbology but without the IR lock diamond.

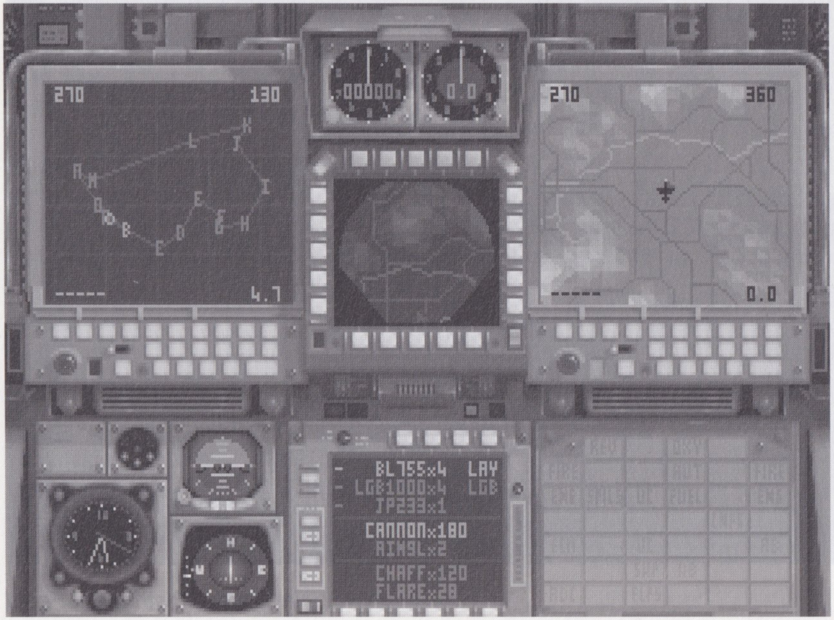
AIRCREW NOTES

Navigator/Weapons Officer's seat

Views available

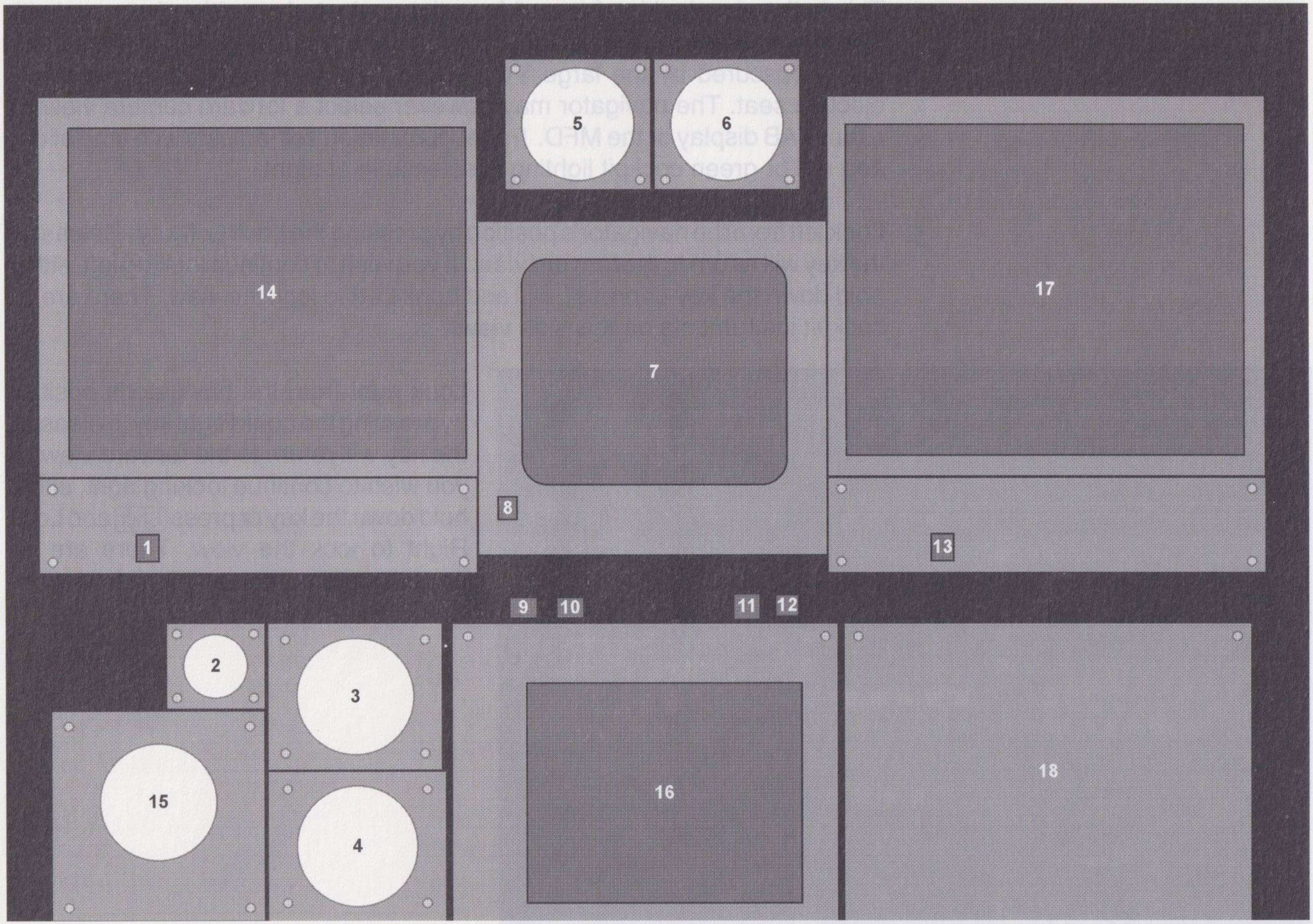
This is the view looking forward from the navigator's position (rear cockpit). The entire screen is occupied by the instrument panel, the view forwards being totally obscured by the large TV TAB displays and the back of the pilot's ejection seat. The navigator may however select a forward camera view on either TAB display or the MFD. Panel illumination self-adjusts with time of day and red or green cockpit lighting is selectable at night.

Look left from the navigator's position by pressing the Look Left key. Releasing the key will return to the forward view. If you wish to continue looking left, either hold down the key or press [Shift] and Look Left to lock the view. There are no cockpit instruments on this side view.



Navigator's Instrument Panel

Look right from the navigator's position by pressing the Look Right key. Releasing the key will return to the forward view. If you wish to continue looking right, either hold down the key or press [Shift] and Look Right to lock the view. There are no cockpit instruments on this side view.



Navigator's Instrument Panel

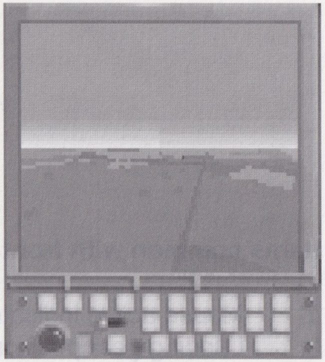
Items common with front cockpit

1 Mouse active indicator
2 Landing gear position indicator
3 Attitude direction indicator
4 Horizontal situation indicator
5 Altimeter
6 Indicated airspeed / Mach number
7 Multi function display
8 Mouse active indicator
9 Autopilot engaged indicator
10 Autothrottle engaged indicator
11 Radar "on" indicator
12 ECM "on" indicator
13 Mouse active indicator

Items unique to rear cockpit

14 Left TV TAB display
15 Analogue clock
16 Stores management display
17 Right TV TAB display
18 Central warning panel

TV TAB displays
Use the Left or Right “TAB Function Select” key to cycle through the following on either display. n.b. the displays are mutually exclusive.


TV TAB Display

(a) Forward looking camera
Provides a daytime forward view and an image-intensified nightime forward view for the navigator.

(b) Scrollable Map
Moving map display used for setting waypoints for targets of opportunity.

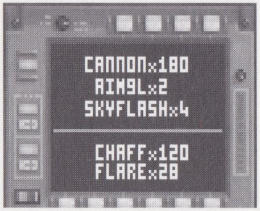
(c) Thermal Imaging and Laser Designation system (TIALD)
Used to pinpoint targets with laser beam from medium altitude.

(d) Flight Plan display (PLN)
Shows aircraft position relative to flightplan.

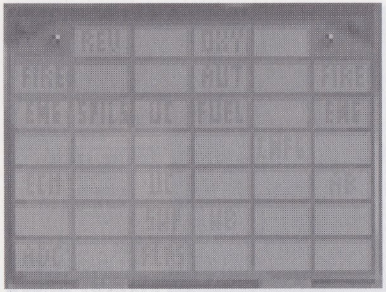
(e) Local map
Zoomable moving map display showing current aircraft position

For a detailed description of each function, please refer to the Avionics Reference section below.

Stores Management Display
This small screen is dedicated to the display of available weapon packages and the selection of weapon delivery modes. All available weapons will be listed together with chaff and flare availability. Packages and delivery modes will usually be allocated during mission planning prior to your flight. If necessary, prior to arming, use the “Select weapon package” key to highlight the required weapon during your approach to the target and use the “Select delivery mode” key to specify your method of attack. The highlighted name will flash once you have armed the weapon.



Stores Management Display



Central Warning Panel

Central Warning Panel

The large panel to the right of the Stores Management Display is used to determine the nature of system failures and warnings. Refer to this panel when the front cockpit attention getters are flashing. You may cancel the attention getters by pressing "master warning reset" key.

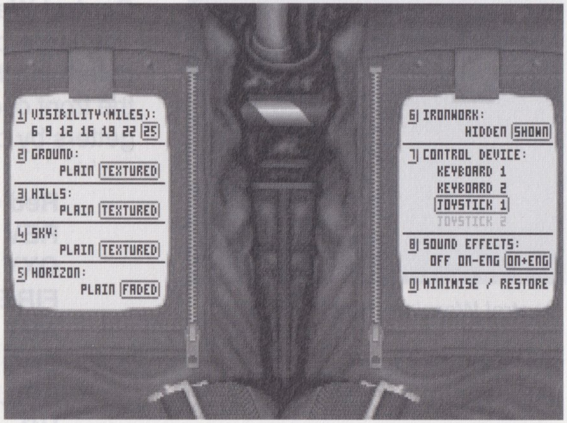
Red Captions:

REV	thrust reversers failure
OXY	oxygen system pressure low
FIRE	engine fire (left or right)
AUT	emergency autopilot disengage
ENG	engine failure (left or right)
SPILS	SPILS spin prevention system damaged
UC	gear damaged
FUEL	fuel low

Amber Captions:

CNFG	flap configuration error
ECM	ECM failure
UC	gear configuration error
AB	air brake failure
SWP	wing sweep failure
WB	wheel brake failure
ADC	air data computer (autopilot) failure
FLPS	flaps failure
MFD1	MFD failure - pilot
MFD2	MFD failure - navigator
HUD	HUD failure
RAD	radar failure
TAB	TV TAB failure (left or right)
RWR	radar warning receiver failure

Kneepad view and options



Look Down View - system configuration

Select the "Look down" view for the following user options:

1	Visibility	6 to 25 miles
2	Ground	plain or textured
3	Hills	plain or textured
4	Sky	plain or textured
5	Horizon	plain or faded
6	HUD frame	hidden or shown
7	Control device	keyboard 1 or 2 joystick 1 or 2
8	Sound effects	off or on
0	Minimise / restore	

Options **1** to **6** adjust aspects of "Tornado" that will affect the smoothness with which it runs on your computer. For example, reducing the Visibility will mean that ground objects cannot be seen until you get closer to them. Less ground detail on the screen will give a smoother simulation on slower computers. Selecting the "plain" options in **2** to **5** will also improve performance on a "slow" computer.

Option **7** allows you to select different primary flight controls:

(i) keyboard 1 - roll rate and pitch rate proportional to how long key is depressed. Roll and pitch rates reduce to zero when key released.
(ii) keyboard 2 - roll rate and pitch rate proportional to how long key is depressed. Roll and pitch rates maintained when key released.
(iii) joystick 1 - single joystick option. Joystick provides pitch and roll control.
(iv) joystick 2 - two joystick option. Joystick 1 provides pitch and roll control. Joystick 2 provides throttle and rudder control.

Option **0** - Reduces Visibility to 6 miles and selects "plain" for options **2** to **5** with single keystroke. This option offers instant frame rate boost - useful in combat. To restore your previous setting hit **0** again.

AVIONICS REFERENCE

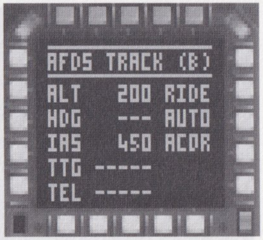
Multi Function Display (MFD)

Mounted centrally on the instrument panel of both pilot and navigator you will see the Multi Function Display, a distinguishing feature of the GR4 Tornado. This unit offers a variety of functions, selected by the “Centre MFD Function Select” key:

(a) Autopilot and Flight Director System (AFDS) and Autothrottle settings - if active
(b) Local map
(c) ILS
(d) Radar - if active
(e) Forward looking camera

(a) Autopilot Flight Director System (AFDS) and Autothrottle
Depending upon the mode selected, the autopilot will take control of your altitude (ALT), your heading (HDG) and your Indicated Air Speed (IAS). Five autopilot modes are available:

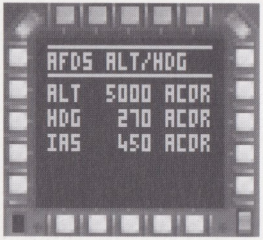
(i) Track
(ii) Altitude/Heading Acquire
(iii) Terrain Follow
(iv) Approach
(v) Autothrottle



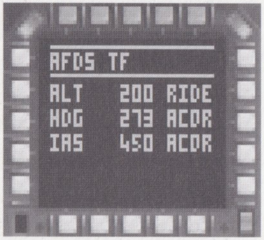
(i) Track (AFDS TRACK (-)) - this mode will command the aircraft to follow a flight plan defined during your pre-flight briefing or to fly to a waypoint set at a target of opportunity during flight (waypoint T). The aircraft will fly automatically from each waypoint to the next, adjusting altitude and speed accordingly. The letter of the next waypoint (e.g. B,C, etc) is shown in brackets at the top of the display. If you wish to bypass the next waypoint, use “skip to next waypoint” key. The system may be toggled between Terrain Follow or Altitude Acquire

when in Track mode by pressing the Terrain Follow key. Altitude acquire (ACQR) or ride height (RIDE) may be adjusted with the pitch control. Heading adjustment is not available in Track mode (HDG display will read AUTO). Time To Go (TTG) is displayed as minutes:seconds. Time Early/Late (TEL) will be displayed if the waypoint has a predefined time of arrival. The autothrottle facility is available in this mode.

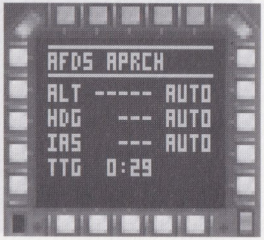
(ii) Altitude/Heading Acquire (AFDS ALT/HDG) - this mode enables you to specify a required barometric altitude and a required heading by using the normal pitch and roll control inputs in conjunction with the AFDS display. ALT and HDG will show ACQR to confirm autopilot acquire mode. The aircraft will make the necessary manoeuvres in order to acquire the conditions specified. Selection of this mode without further control input will cause the aircraft to hold the current altitude and heading. The autothrottle facility is available in this mode.

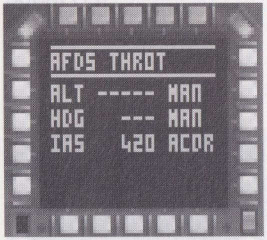


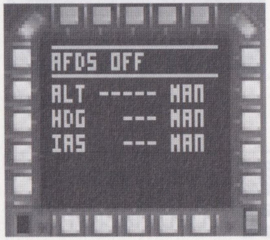
(iii) Terrain Follow (AFDS TF) - this mode instructs the autopilot to fly your aircraft at a given ride height (RIDE) above the ground, selectable in seven stages from 200 feet up to 1500 feet using the normal pitch control input. Roll control sets desired heading as in Altitude/Heading Acquire mode. The system will do its best to follow the contours of the ground, thereby minimising your exposure to enemy radar. Watch for the “B risk” indicator when travelling at high speed on the lowest ride heights. This warning light illuminates when the system believes that it may not be possible to maintain the desired safety margin - ignore it and you may find yourself crashing into a hillside. Either slow down or increase your ride height. If the radar altitude falls below the safety margin the AFDS will roll the wings level, execute a hard pull up, disengage itself and trigger a warning. The autothrottle facility is available in this mode.

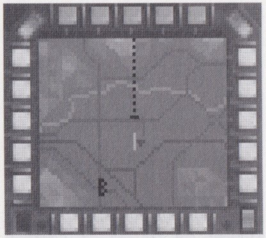


(iv) Approach (AFDS APRCH) - links the autopilot to the Instrument Landing System for an automatic approach to an allied airfield. Altitude (ALT), heading (HDG) and airspeed (IAS) are all under autopilot control (AUTO). Time To Go (TTG) is displayed as minutes:seconds. An AFDS approach is manually selectable only if you are within an allied ILS beam and flying towards the airfield. At this point the ILS marker will be on your HUD and the localiser/








Local Map Mode

glideslope needles will have appeared on your MFD if it is in ILS mode. The Approach mode is automatically selected when you arrive at an approach waypoint in Track mode. Once active, the autopilot will steer the aircraft onto the correct approach path to the runway and adjust throttle setting for correct speed and rate of descent. n.b. This is an "auto-approach" mode not an "auto-landing" mode. During your "hands off" approach, it will be necessary for you to make the appropriate adjustments to wing sweep, flaps, gear etc. while the autopilot does the hard work of adjusting speed, heading and rate of descent. You will also need to cancel the autopilot just prior to touchdown, flare, land, apply reverse thrust, brake etc.....

(v) Autothrottle - (AFDS THROT) -this facility allows you to set a desired airspeed and may be used independently or in conjunction with AFDS modes (i) to (iii) described above. Selection is confirmed by IAS changing from manual (MAN) to acquire (ACQR) and illumination of the "autothrottle engage indicator". When active, the normal throttle control is used to set the desired speed on the AFDS display. The autothrottle system will adjust the engine thrust accordingly in an attempt to maintain the demanded speed. However, please note that this is not possible in all circumstances e.g. in a steep climb or dive or high "g" turn.

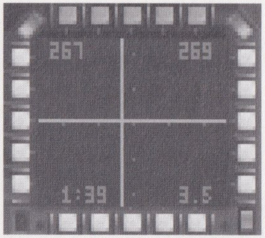
Finally, if you disengage the autopilot, pitch and roll control revert to manual (MAN) and the MFD will confirm AFDS OFF if autothrottle is not active, or AFDS THROT if autothrottle is active.

(b) Local Map

This is a moving map display orientated about your present position. The display shows hills, roads, rivers, airfields (active runway in white) and waypoints (B,C,D etc). The map origin may be toggled between the centre of the display or at the base of the display. Your aircraft is always at the map origin, heading along the dotted flightpath. The scale of the map is selectable (i.e. zoom in and out) from 0.5nm, 1nm, 2nm, 4nm, 8nm and 16 nm with a base origin.

(c) Instrument Landing System (ILS)

Select this display during your final approach to see the ILS localiser and glideslope indicators. Additional information on this screen includes aircraft heading (top left corner), bearing to the runway mid-point (top right corner), estimated time to touchdown (lower left corner) and distance to runway mid-point (lower right corner).

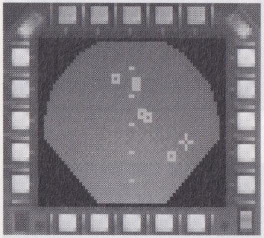


ILS Mode

(d) Radar

The radar has two independent modes of operation,each with on/off control. If the desired radar mode does not appear as you cycle through the MFD functions, first check that the radar is switched on.

(i) air mode - used for detecting, designating and tracking aircraft. The air radar is a plan view display showing target range and bearing only. Both enemy and allied aircraft are shown, differentiated by symbology. Use your mouse to move the designator symbol to coincide with the chosen target and designate with the left mouse button. Designation may be cancelled with the right mouse button. If the designator does not appear to respond to the mouse, check that the MFD is the active display for the mouse by pressing the Tab key.

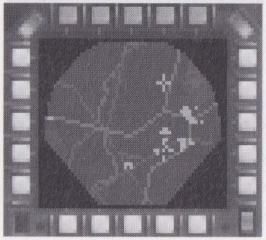

Air Radar Mode

ENEMY AIRCRAFT
ALLIED AIRCRAFT

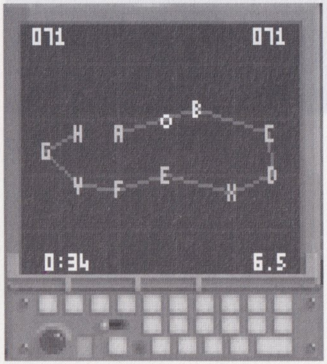
Air Radar Symbology

The ADV air radar has three selectable ranges: 30 nm (for use with Sky Flash), 10 nm (for use with AIM9-L) and 2 miles (for use with guns). The IDS radar has only the 10 nm and 2nm range settings. It is also possible to lock on to a target visually through the HUD by using the boresight designate key. Please note that use of the radar at very low altitudes will be affected by terrain masking i.e. it cannot see through hills!

(ii) ground mode - used primarily for detecting, designating and tracking military ground vehicles.The display is a composite image of radar returns and digital map data which are compared to identify and highlight vehicles. Due to terrain masking, vehicle returns may be intermittent whereas mapped features will always be shown. Use your mouse to move the designator symbol to coincide with the chosen target position and designate with the left mouse button. Designation may be cancelled with the right mouse button. If the


Ground Radar Mode

Forward Looking Camera



TAB PLN Display

designator does not appear to respond to the mouse, check that the MFD is the active display for the mouse by pressing the Tab key.

The IDS radar has six selectable ranges:0.5nm, 1nm, 2nm, 4nm, 8nm and 16nm. The ADV is not fitted with a ground radar.

(e) Forward looking camera
This display provides a daytime forward view for the navigator and an image-intensified view for both crew at night.

TV TAB displays (navigator's cockpit)

Both left and right TV TAB displays offer a variety of functions on a mutually exclusive basis. Items such as Forward Looking Camera and local map are also available on the central MFD. Functions are selected by repeatedly pressing the Left (or Right) Tab Function Select key:

(a) Flight Plan Display (PLN)
(b) Thermal Imaging and Laser Designating (TIALD)
(c) Scrollable map
(d) Local map
(e) Forward looking camera

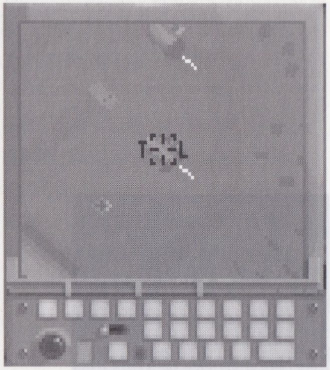
It is also possible to switch off each TV Tab display.

(a) Flight Plan Display (PLN)
Normally displayed on the left hand TV TAB, this option shows your aircraft position relative to your flightplan. All pre-planned waypoints are shown (A,B,C etc) plus any target of opportunity waypoint (T) set during flight. The scale of the display adjusts automatically in order to keep both your current position (small circle) and your pre-planned flight path on the display simultaneously. Also appearing on the Flight Plan Display are aircraft heading (top left corner), bearing of next waypoint (top right corner), estimated time to next waypoint (lower left corner) and distance to next waypoint (lower right corner). n.b. The

estimated time will only be displayed if you are heading in the general direction of the next waypoint, otherwise calculation would be impossible.

(b) Thermal Imaging and Laser Designating (TIALD)

This is a steerable plan view camera with laser designator. It is capable of looking ahead, behind and to the sides of your aircraft. Its range increases with altitude and ideally it would be used at above 20,000 feet in order to give the widest field of view. Camera steering and target designation is by means of the mouse. As the camera looks ahead of your aircraft, the designator symbol changes to confirm this fact. It is recommended that you designate targets ahead of your aircraft in order to give the laser-guided bombs sufficient time to reach their targets. A continuous zoom facility allows pin-point accuracy. Prior to take-off this equipment does not function and the TV Tab will display a large cross.



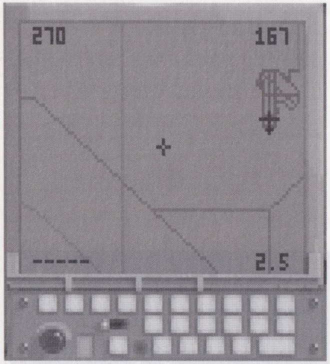
TIALD Display

(c) Scrollable map

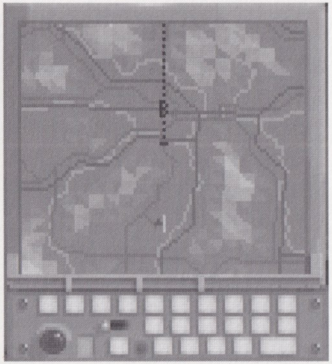
This is a slewable map on which the navigator may designate and select a target of opportunity waypoint (waypoint T). Map scale is selectable from 0.75nm up to 24nm. Unlike the Local map where your aircraft is fixed at the centre or bottom centre of the display, on the scrollable map your aircraft symbol scrolls with the map and may leave the display altogether. Pressing the "locate aircraft" key will centre the map at your current position if you are within the boundaries of the map. Pressing the "locate target" key will centre the map at the position of waypoint T if set. Additional navigational data is presented in each corner:

Upper left: aircraft heading
Upper right: bearing to position of cursor
Lower left: estimated time to reach position of cursor
Lower right: distance in n.m. to position of cursor

n.b. If you are flying away from the cursor position, it is not possible to display an estimated time.



TAB Scrollable Map



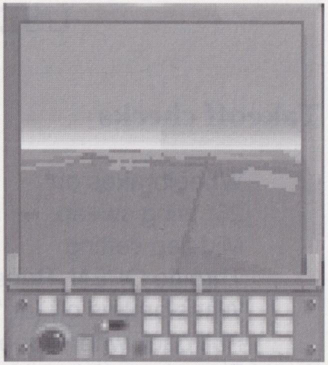
TAB Local Map

(d) Local map

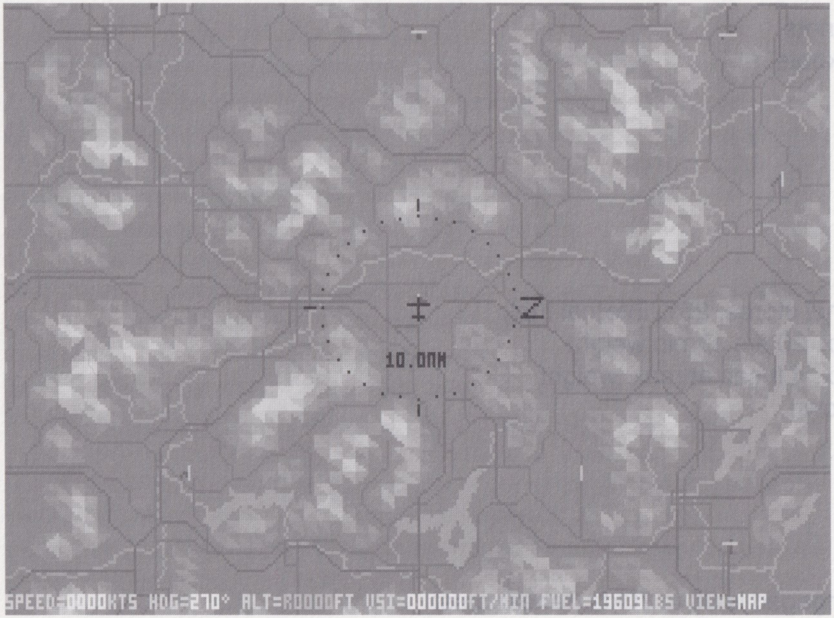
This is very similar to the Local Map mode of the MFD but with selectable ranges from 0.75nm, 1.5nm, 3nm, 6nm, 12nm and 24 nm with the base origin.

(e) Forward looking camera

This display provides a daytime forward view for the navigator and an image-intensified nightime forward view for the navigator.



TV TAB Forward Looking Camera



Full Screen Moving Map

Full-Screen Moving Map

A full screen moving map display is available with zoom controls. The boundaries of the combat zone are not shown. The map is always centred at your present point and orientated so that you are flying directly up the screen. Please note that the simulation continues in real time when this map is displayed. For safety reasons we recommend that you select autopilot before switching to the map.

USEFUL CHECKLISTS

Takeoff checks

Wheelbrakes on
25° wing sweep
Mid flap setting
Throttle OPEN, Reheat ON FULL
Wheelbrakes off (at 100% rpm and max. reheat)
Pull back when speed above 140 knots
Do not rotate beyond 15° nose up
Gear UP after takeoff
Maintain climb angle of between 10° and 20° (1st and 2nd pitch bars on HUD)
Flaps UP when speed above 215 knots
Select 45° wing sweep above 350 knots

Landing checks

25° wing sweep
Full flap setting
Gear down
Airspeed approx. 150 kts (no external stores, 25% internal fuel)
Descent rate at touchdown: max. 20 ft/s at min.weight
max. 4 ft/sec at max. weight
Engage reverse thrust after touchdown
Open throttle to 100%
Monitor speed
Throttle to idle at 80kts
Disengage reverse thrust
Apply wheelbrakes

n.b. Minimum speed with reverse thrust engaged is 50 to 70kts (reheat must not be used)

Limiting speeds

Vmax sea level	Mach 1.2+
Vmax 36000 ft	Mach 2.2
Vmax for each wing sweep	
at 25° sweep:	Mach 0.73
at 45° sweep:	Mach 0.88
at 67° sweep:	Mach 2.20
Vmax manoeuvre flaps	450 kts IAS
Vmax mid flaps	280 kts IAS
Vmax full flaps	225 kts IAS
Vmax u/c down	350 kts (warning at 250kts)

The following speeds will vary with aircraft weight:

Vstall 25° sweep (power off)	135 kts (zero flaps)
Vstall 25° sweep (power off)	120 kts (mid flaps)
Vstall 25° sweep (power off)	108 kts (full flaps)
Vstall 45° sweep	155 kts (zero flaps)
Vstall 67° sweep	182 kts

max positive g	7.5
max negative g	-3
max roll rate	180°/sec

Approach & landing emergencies:

Landing with wings swept or flap failure:

1. Jettison all stores
2. See table below for approach speed

After touchdown:

3. Throttle to idle
4. Lower nosewheel
5. Engage thrust reverse
6. Throttle to 80%
7. Throttle to 100% at 130 kts
8. Throttle to idle at 85 kts
9. Apply wheelbrakes

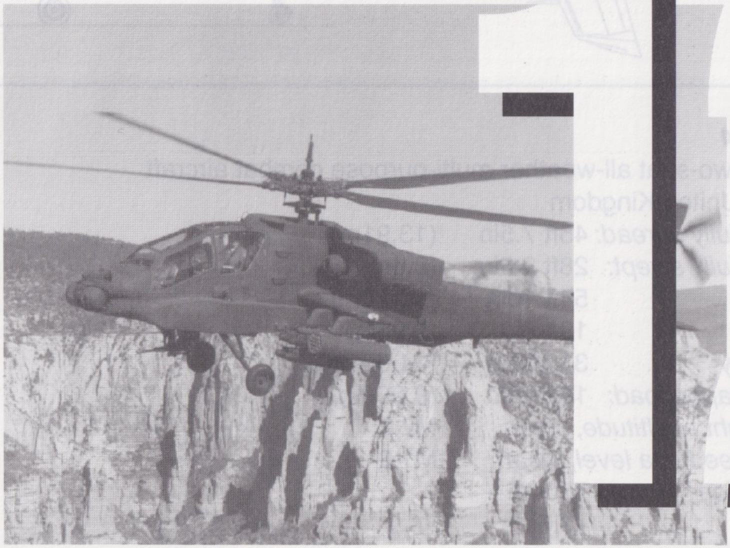
wing sweep	*flaps*	*speed*	*AoA*	
25	up	180	12	add 7kt per 1000 kg above 15000 kg
	mid	164	9	
45	up	199	13	add 5kt per 1000 kg above 15000 kg
67	up	208	16	

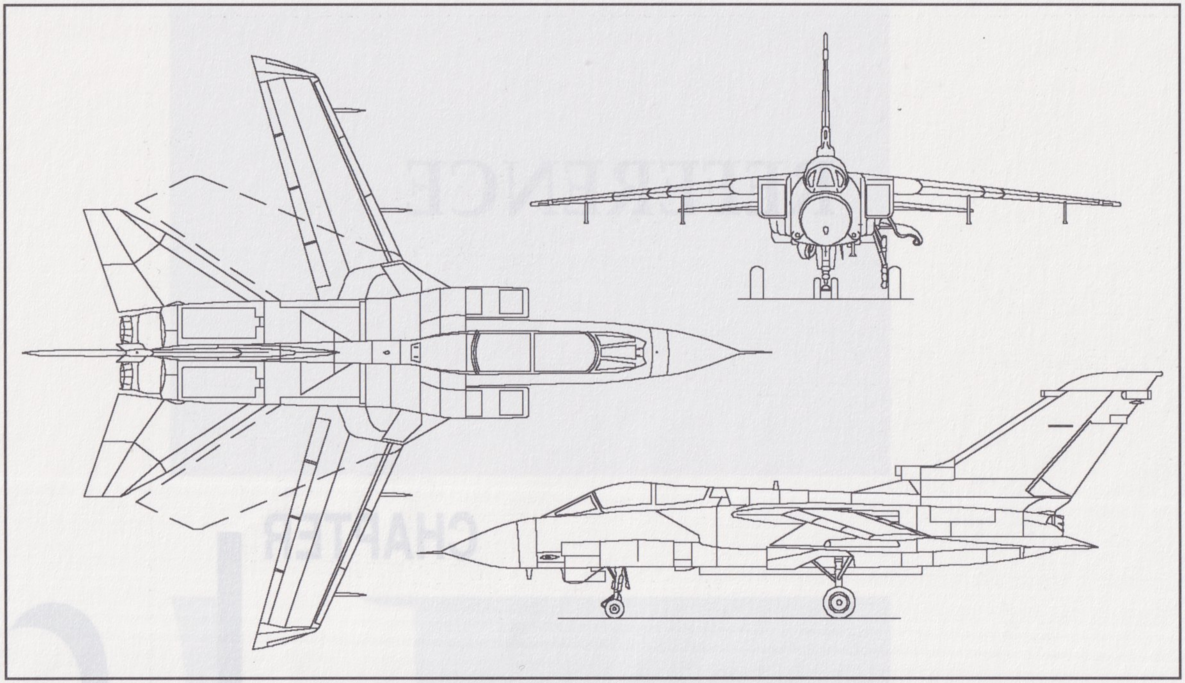
Spin recovery procedure:

1. Select 25 sweep
2. Identify direction of rotation
3. Stick **back**
4. **Pro**-spin aileron i.e. push stick in direction of rotation
5. Hold until spin stops
6. Centralise stick
7. Open throttle

REFERENCE

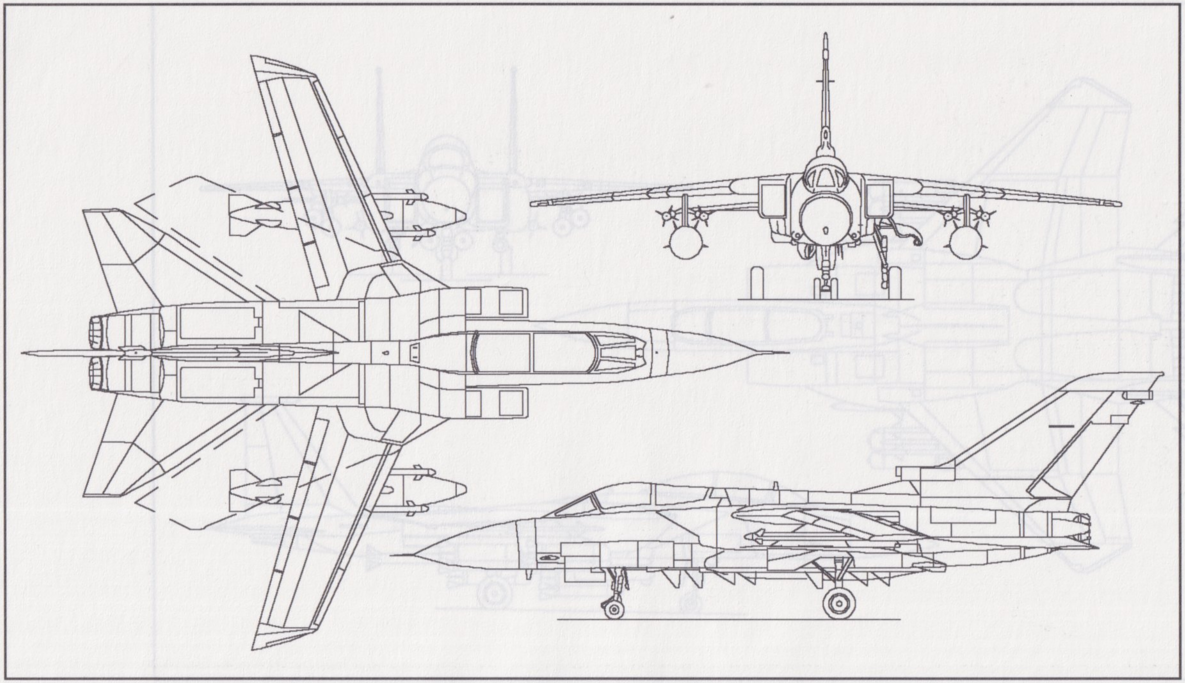
CHAPTER 12





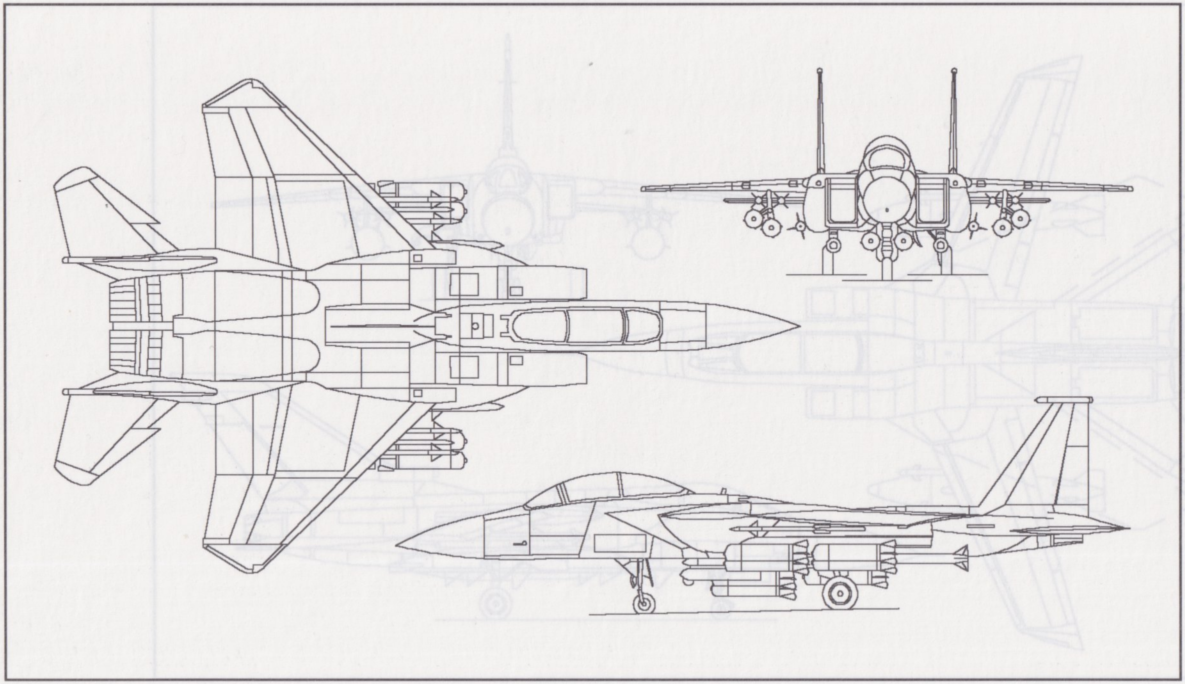
Tornado GR4

Category:	two-seat all-weather multi-purpose combat aircraft		
Origin:	United Kingdom		
Wing span:	*fully spread:*	45ft 7.5in	(13.91m)
	fully swept:	28ft 2.5in	(8.6m)
Length:		54ft 10in	(16.72m)
Height:		19ft 6in	(5.95m)
Weight, empty		31,065lb	(14,091kg)
Maximum weapon load:		19,840lb	(9,000kg)
Max. level flight at altitude, clean			M2.2
Max. level speed sea level, clean			M1.2
Radius of action		750nm	
g limit		+7.5	



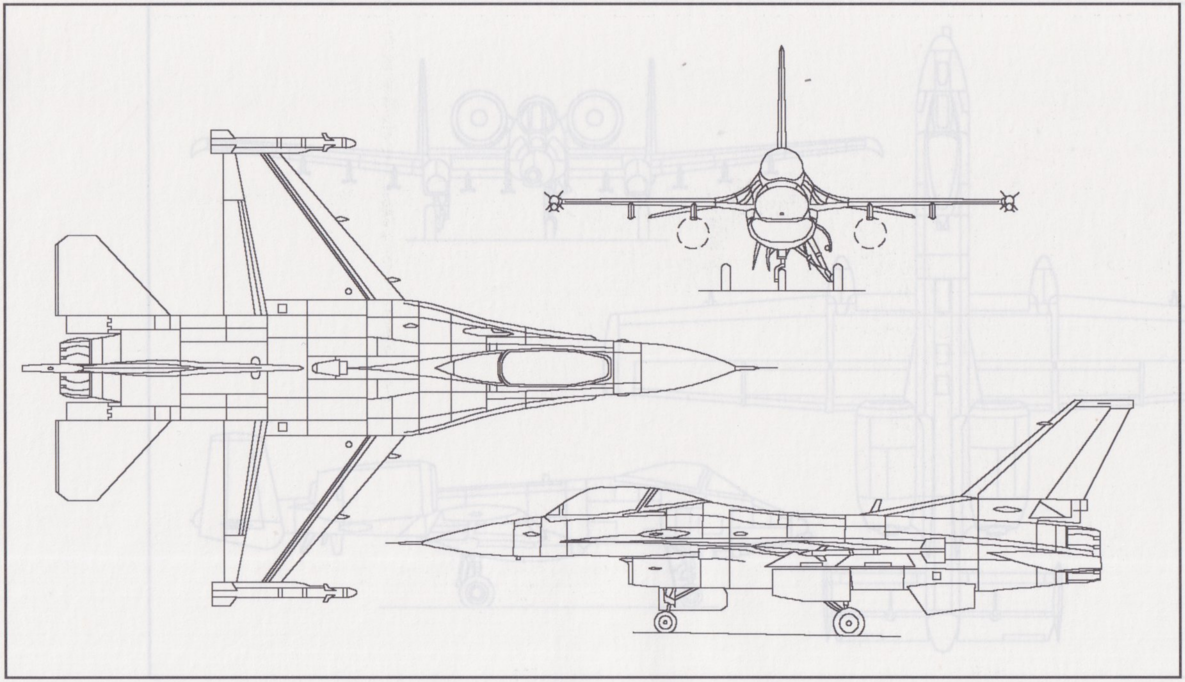
Tornado F3

Category:	two-seat all-weather air defence interceptor		
Origin:	United Kingdom		
Wing span:	*fully spread:*	45ft 7.5in	(13.91m)
	fully swept:	28ft 2.5in	(8.6m)
Length:		61ft 3in	(18.68m)
Height:		19ft 6in	(5.95m)
Weight, empty		31,970lb	(14,500kg)
Maximum weapon load:		18,740lb	(8,500 kg)
Max. level flight at altitude, clean			M2.2
Max. level speed sea level, clean			M1.2
Radius of action		1000nm	
g limit		+7.5	



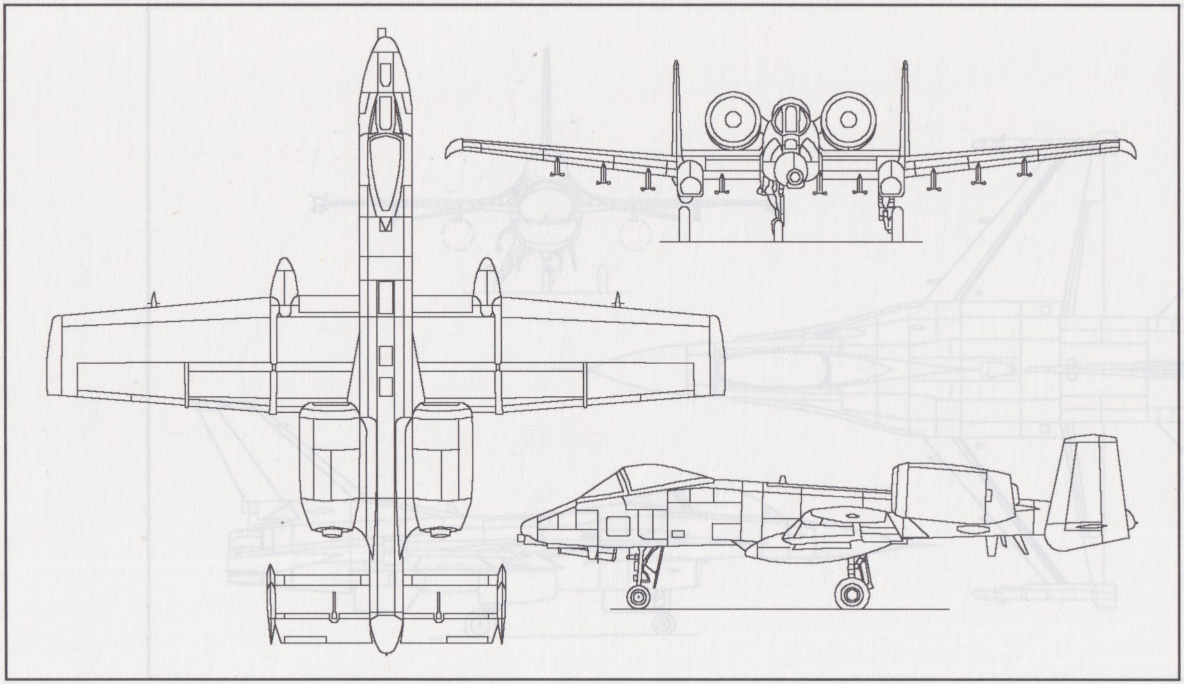
F-15 Eagle

Category:	single-seat air superiority fighter	
Origin:	USA	
Wing span:	42ft 10in	(13.05m)
Length:	63ft 9in	(19.43m)
Height:	18ft 5.5in	(5.63m)
Weight, empty	31,700lb	(14,379kg)
Max. weapon load:	24,500lb	(11,113kg)
Max. level flight at altitude, clean		M2.5
Radius of action	685nm	
g limit	+7.3	



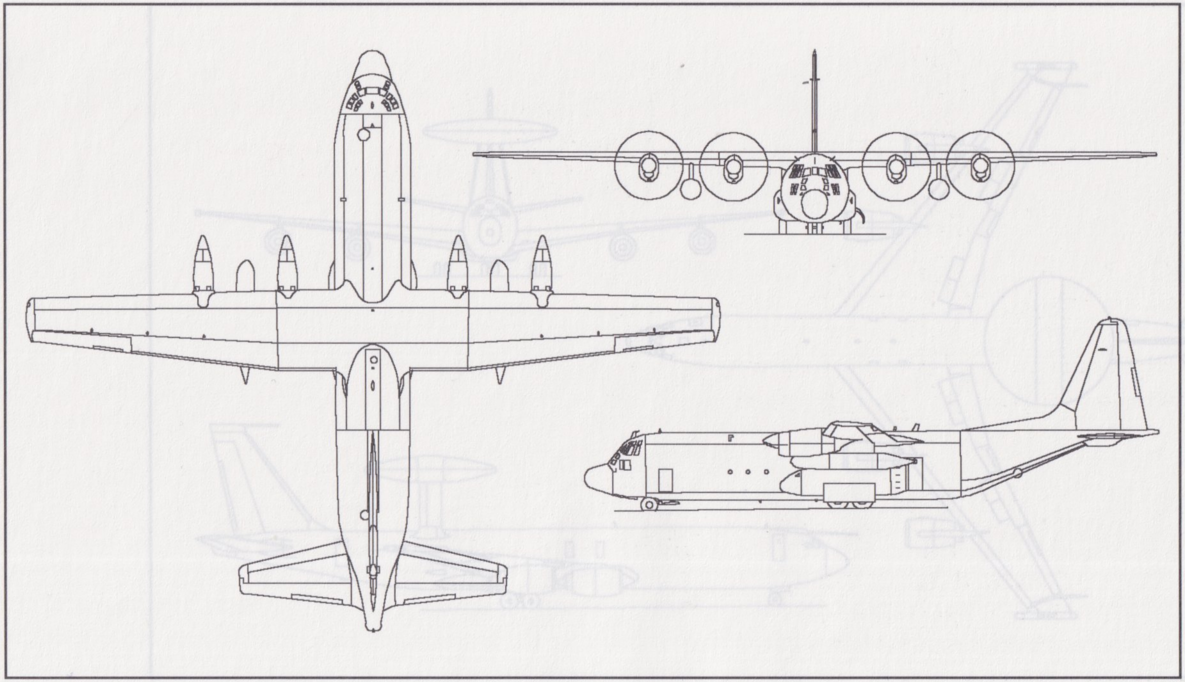
F-16C Fighting Falcon

Category:	single-seat multi-role fighter	
Origin:	USA	
Wing span:	31ft 0in	(9.45m)
Length:	47ft 8in	(14.52m)
Height:	16ft 5in	(5.01m)
Weight, empty	18,238lb	(8,273kg)
Max. weapon load:	12,000lb	(5,443kg)
Max. level flight at altitude, clean		M2.5
Radius of action	500+nm	
g limit	+9	



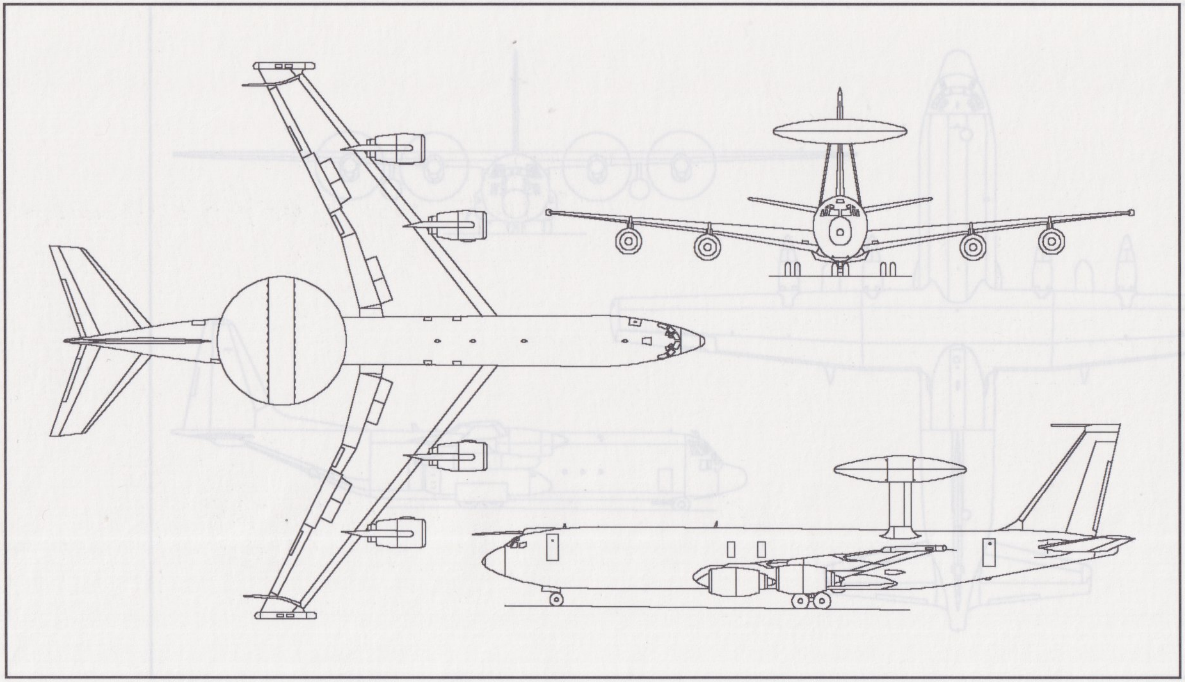
A-10 Thunderbolt

Category:	single-seat close support aircraft	
Origin:	USA	
Wing span:	57ft 6in	(17.53m)
Length:	53ft 4in	(16.26m)
Height:	14ft 8in	(4.47m)
Weight, empty	24,959lb	(11,321kg)
Max. weapon load:	16,000lb	(7,250kg)
Max. level flight at sea level, clean		381kt
Radius of action	250nm	



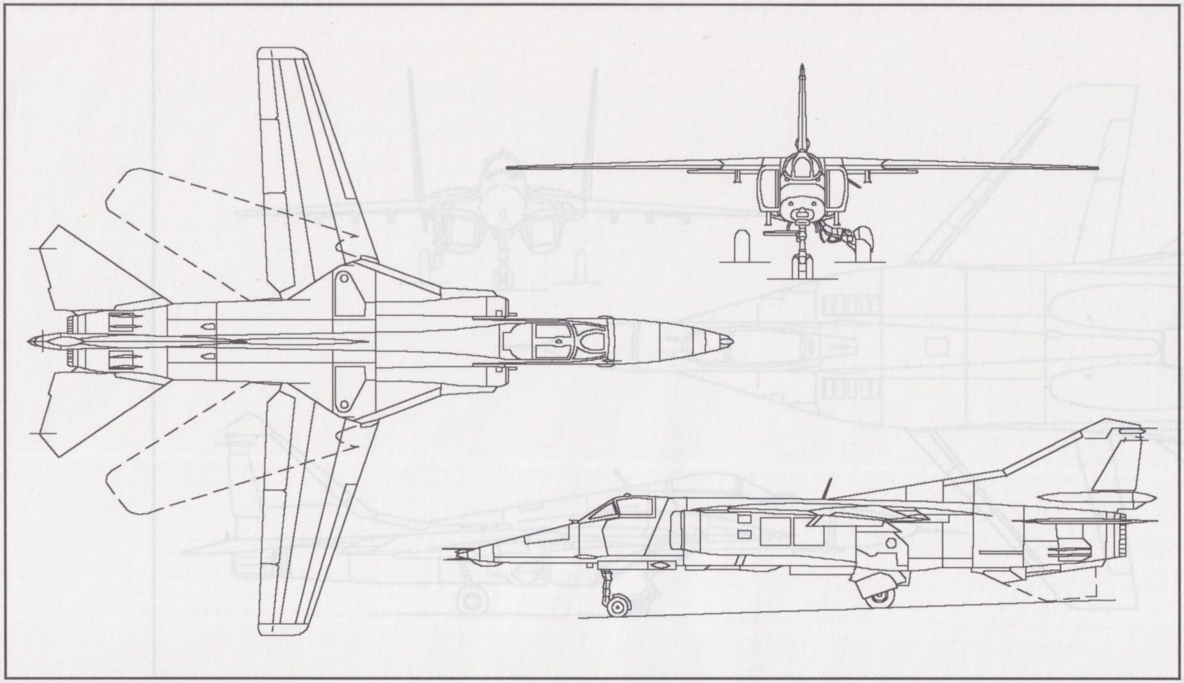
C-130H Hercules

Category:	medium/long range combat transport	
Origin:	USA	
Wing span:	132ft 7in	(40.41m)
Length:	97ft 9in	(29.79m)
Height:	38ft 3in	(11.66m)
Weight, empty	76,469lb	(34,686kg)
Max. cruising speed	325kts	
Radius of action	2,046nm	



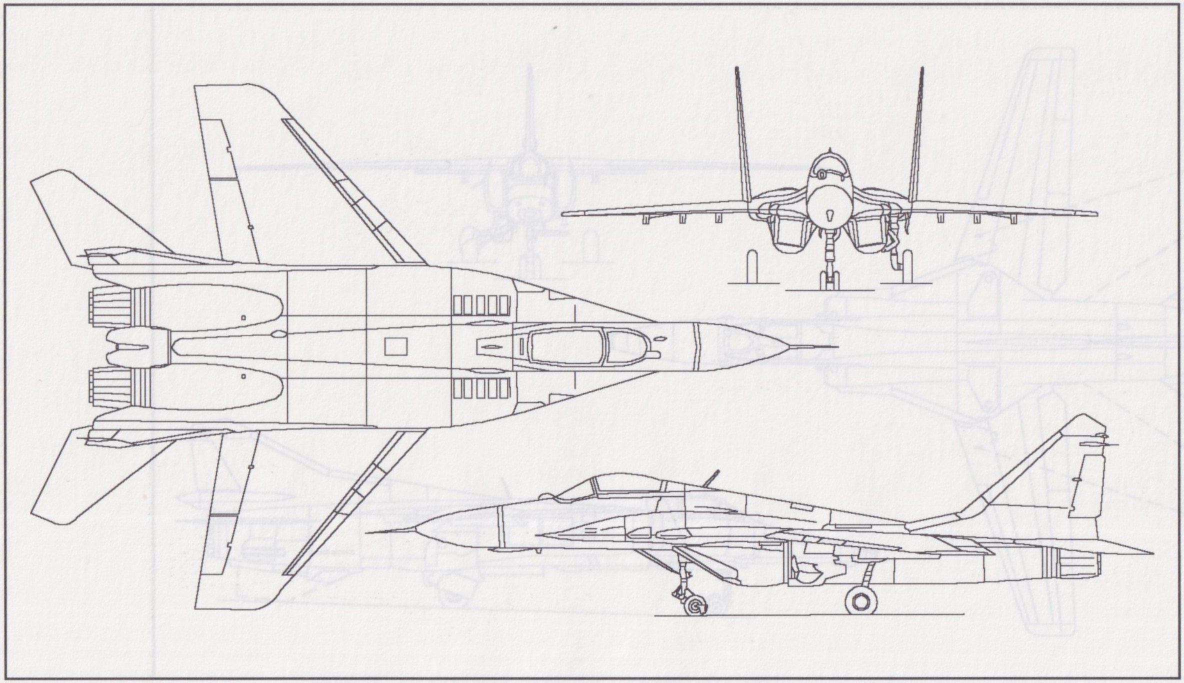
E-3D Sentry

Category:	Airborne early warning and command post	
Origin:	USA	
Wing span:	145ft 9in	(44.42m)
Length:	152ft 11in	(46.61m)
Height:	41ft 9in	(12.73m)
Weight, max. T-O	335,000lb	(151,953kg)
Max. level speed	460kts	
Endurance on station	870m	



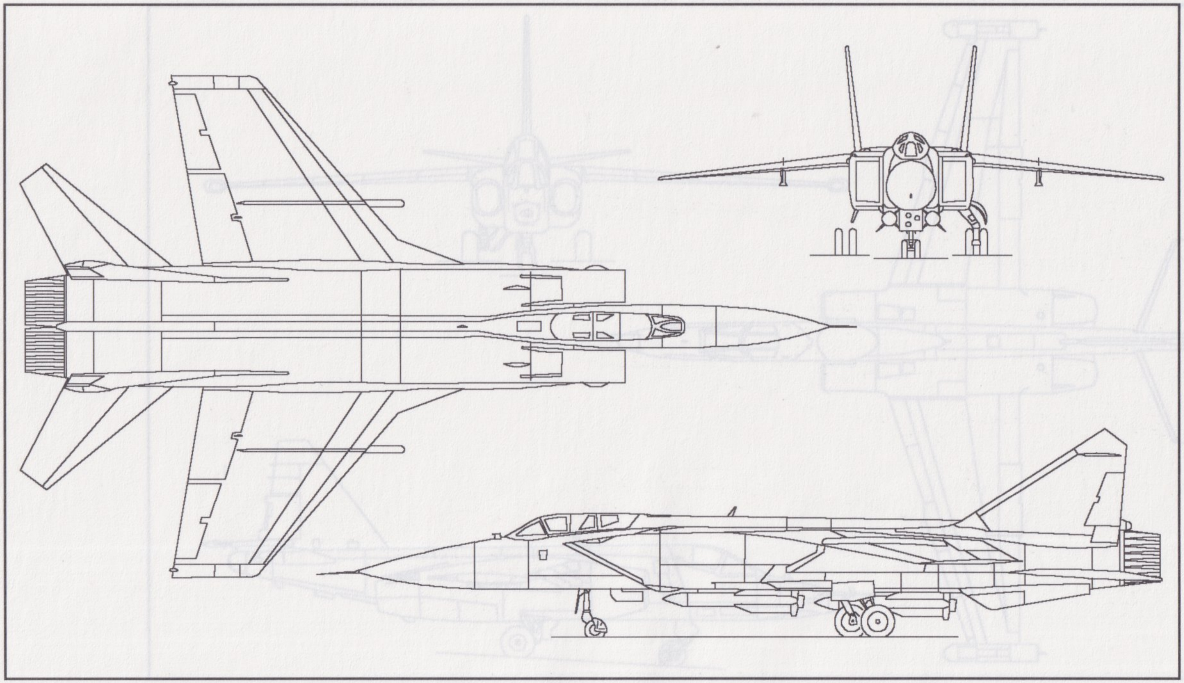
MiG 27 Flogger

Category:	single-seat ground attack aircraft		
Origin:	CIS		
Wing span:	*fully spread:*	45ft 10in	(13.965m)
	fully swept:	25ft 6in	(7.78m)
Length:		56ft 1in	(17.1m)
Height:		15ft 10in	(4.82m)
Weight, empty		23,590lb	(10,700kg)
Maximum weapon load:		9,920lb	(4,500kg)
Max. level flight at altitude, clean			M1.77
Max. level speed sea level, clean			M1.1
Radius of action		210nm	
g limit		+7	



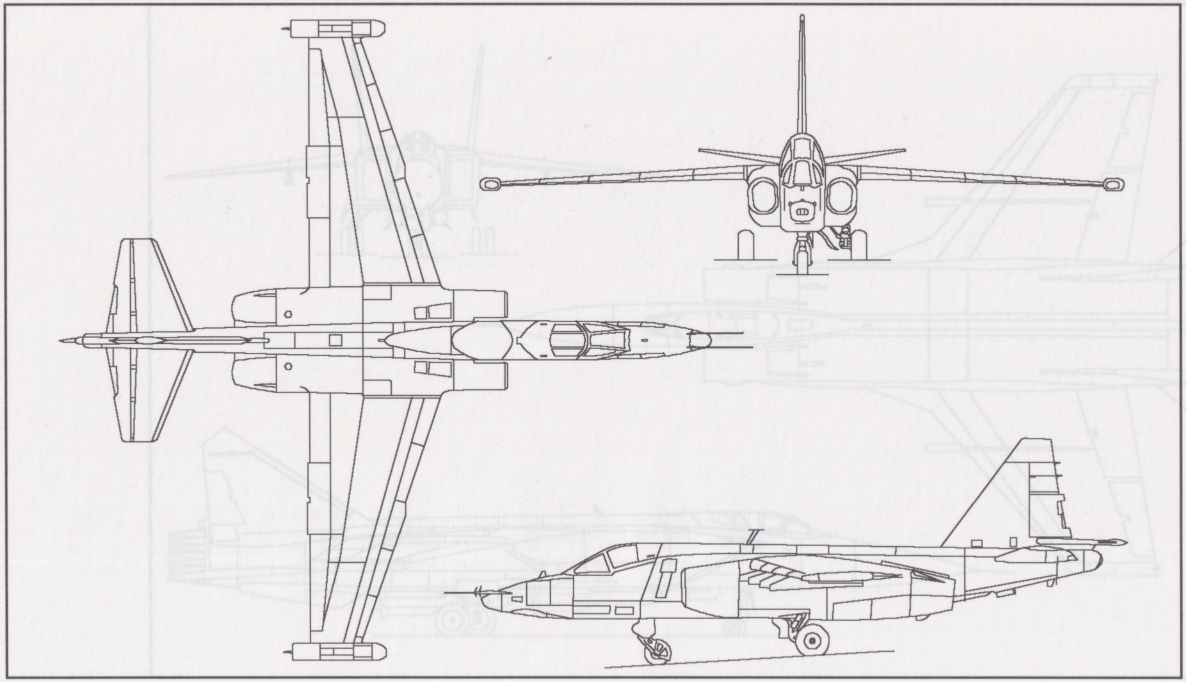
MiG 29 Fulcrum

Category:	single-seat counter-air fighter	
Origin:	CIS	
Wing span:	37ft 3in	(11.36m)
Length:	56ft 10in	(17.32m)
Height:	15ft 6in	(4.73m)
Max. T-O weight,	39,700lb	(18,000kg)
Max. level flight at altitude, clean		M2.3
Max. level speed sea level, clean		M1.06
Radius of action	600nm	
g limit	+9	



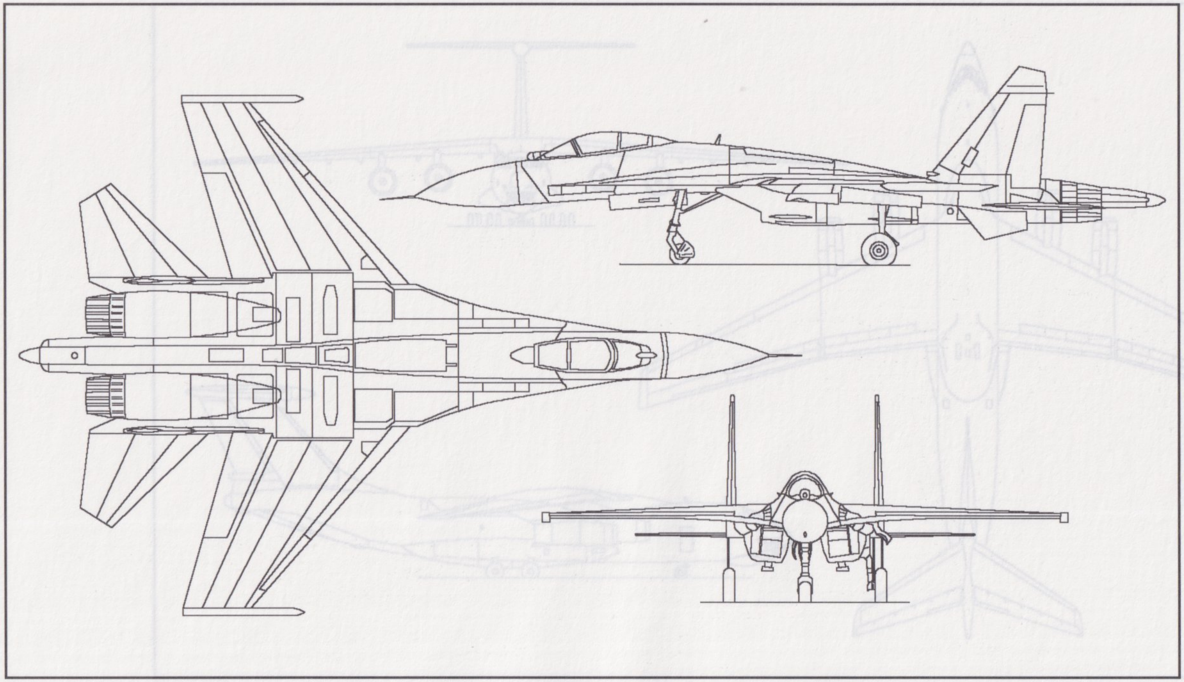
MiG 31 Foxhound

Category:	two-seat all-weather interceptor	
Origin:	CIS	
Wing span:	45ft 11in	(14.0m)
Length:	70ft 6.5in	(21.5m)
Height:	18ft 4in	(5.6m)
Weight, empty	48,115lb	(21,825kg)
Maximum T-O weight:	90,725lb	(41,150kg)
Max. level flight at altitude, clean		M2.4
Max. level speed sea level, clean		M1.1
Radius of action	1,135nm	
g limit	+5	



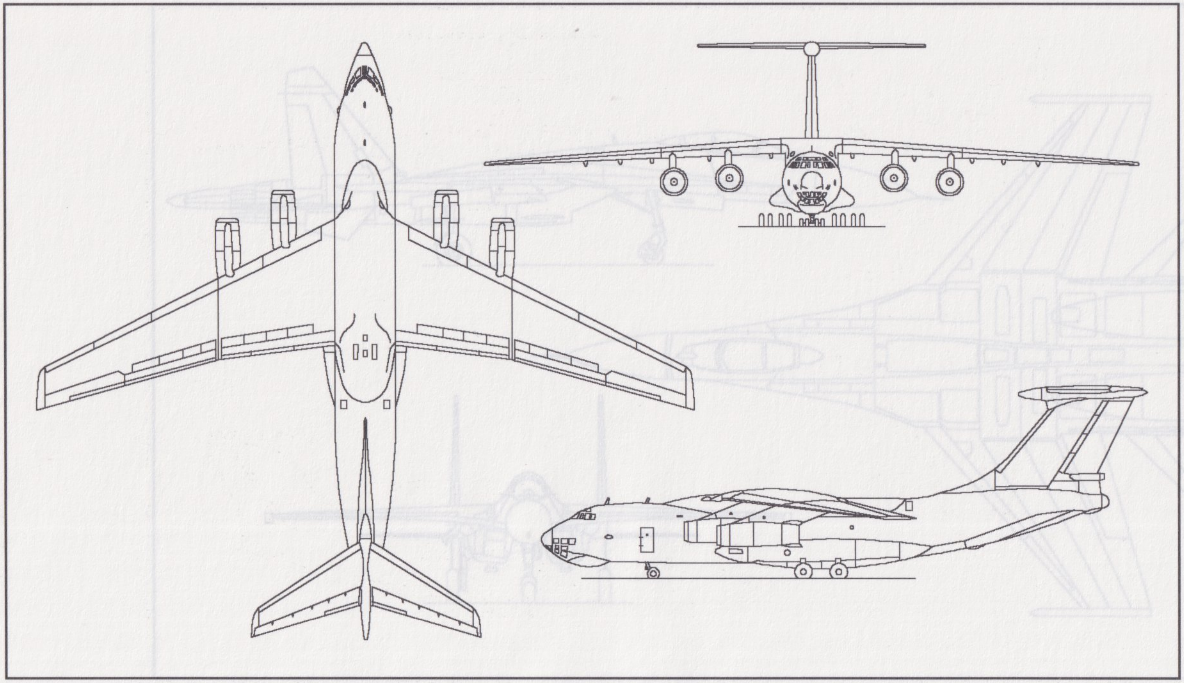
Su-25 Frogfoot

Category:	single-seat close support aircraft	
Origin:	CIS	
Wing span:	47ft 1.5in	(14.36m)
Length:	50ft 11.5in	(15.53m)
Height:	15ft 9in	(4.8m)
Max. T-O weight,	20,950lb	(9,500kg)
Max. level speed sea level, clean		M0.8
Radius of action	405nm	
g limit	+6.5	



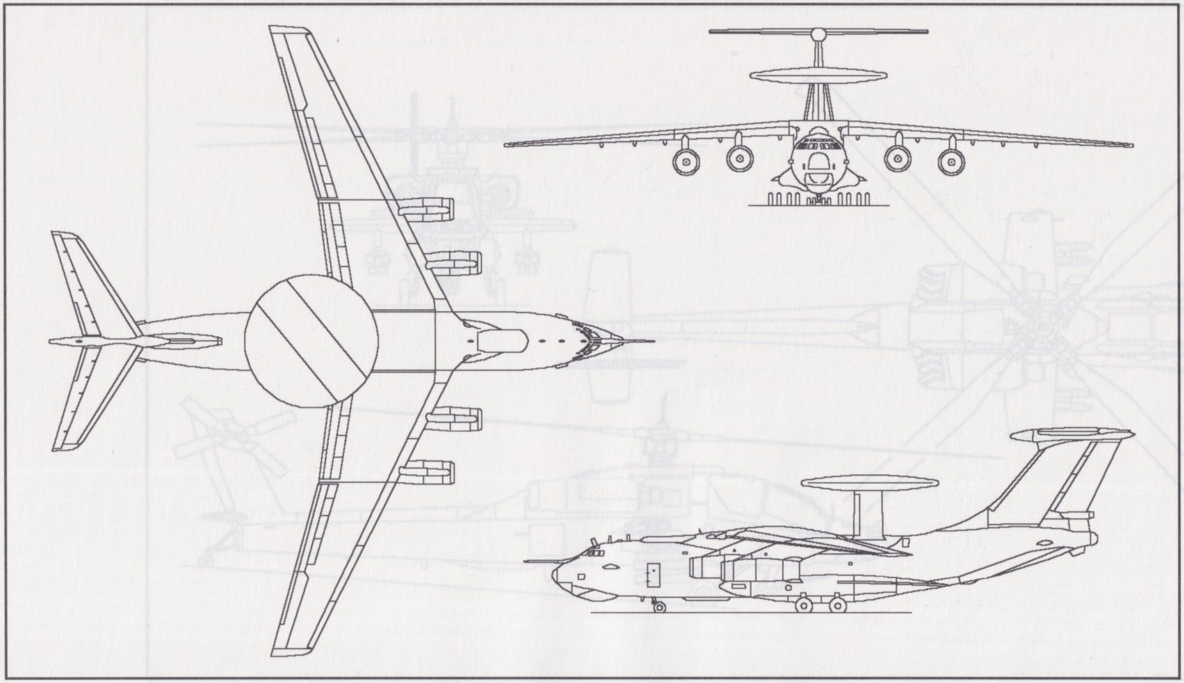
Su-27 Flanker

Category:	single-seat counter-air fighter	
Origin:	CIS	
Wing span:	48ft 3in	(14.7m)
Length:	71ft 11.5in	(14.7m)
Height:	19ft 5.5in	(5.93m)
Max. T-O weight,	49,600lb	(22,500kg)
Max. level flight at altitude, clean		M2.35
Max. level speed sea level, clean		M1.1
Radius of action	810nm	
g limit	+9	



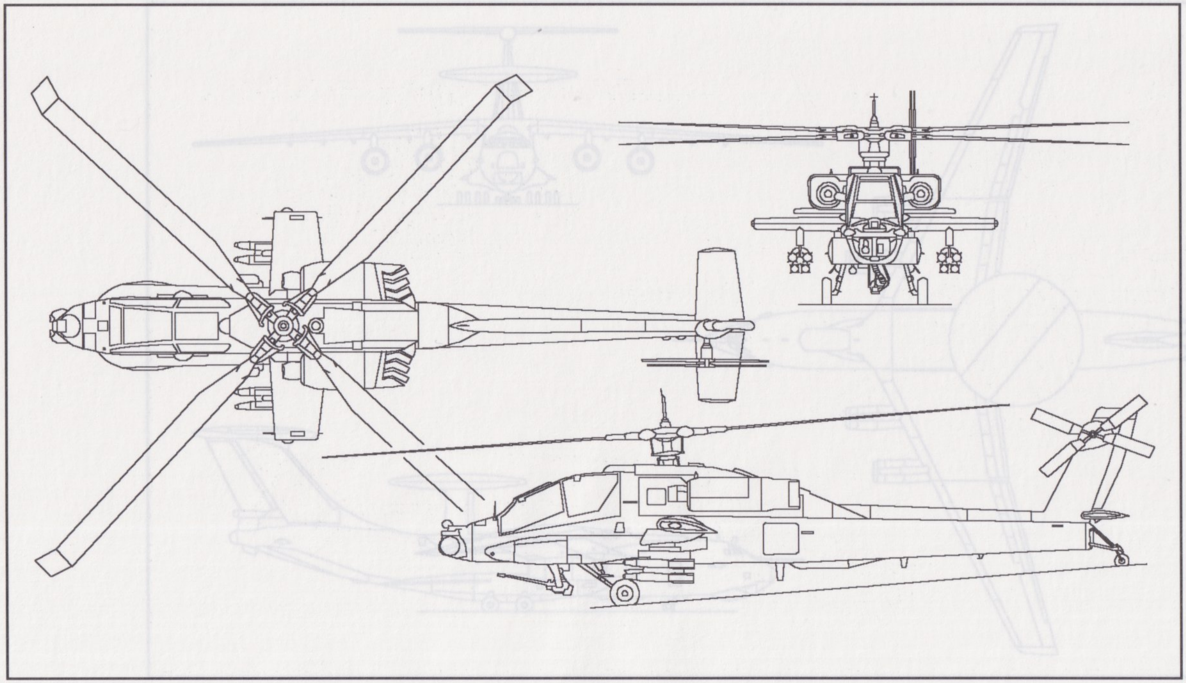
Il-76 Candid

Category:	medium/long range combat transport	
Origin:	CIS	
Wing span:	165ft 8in	(50.5m)
Length:	152ft 10in	(45.59m)
Height:	48ft 5in	(14.76m)
Max. T-O weight,	418,875lb	(190,000kg)
Max. level speed sea level, clean		459kts
Radius of action	2,700nm	



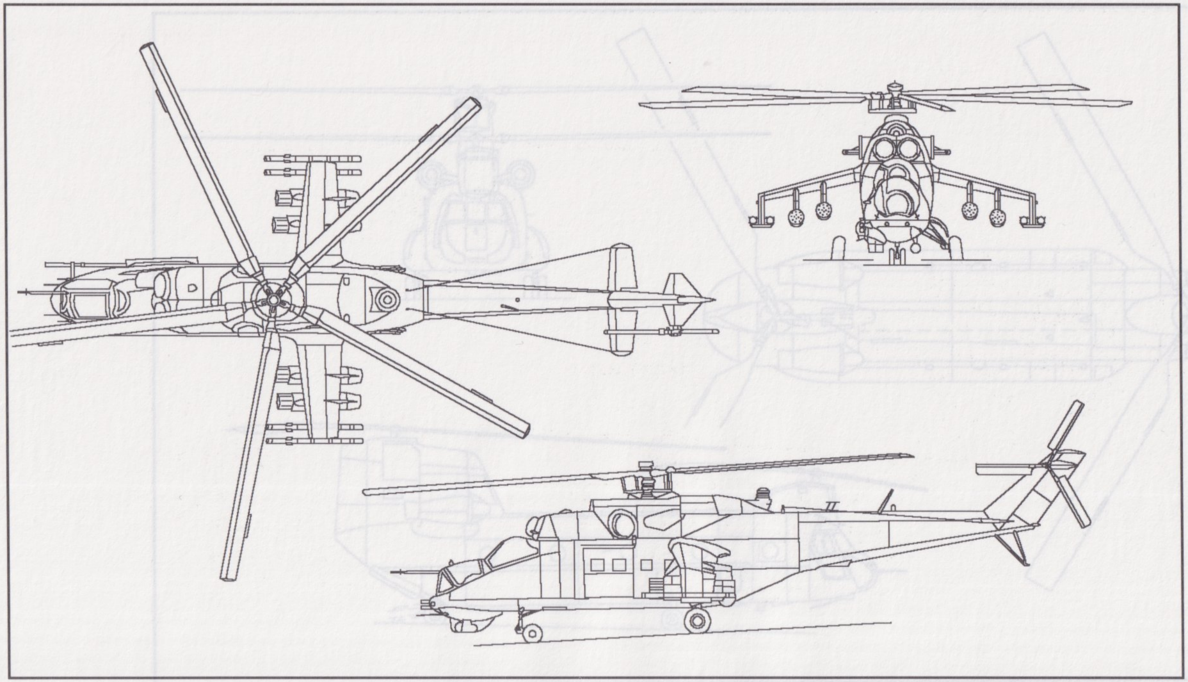
A-50 Mainstay

Category:	airborne early warning	
Origin:	CIS	
Wing span:	165ft 8in	(50.5m)
Length:	152ft 10in	(45.59m)
Height:	48ft 5in	(14.76m)
Max. T-O weight,	418,875lb	(190,000kg)
Max. level speed sea level, clean		459kts
Radius of action	2,700nm	

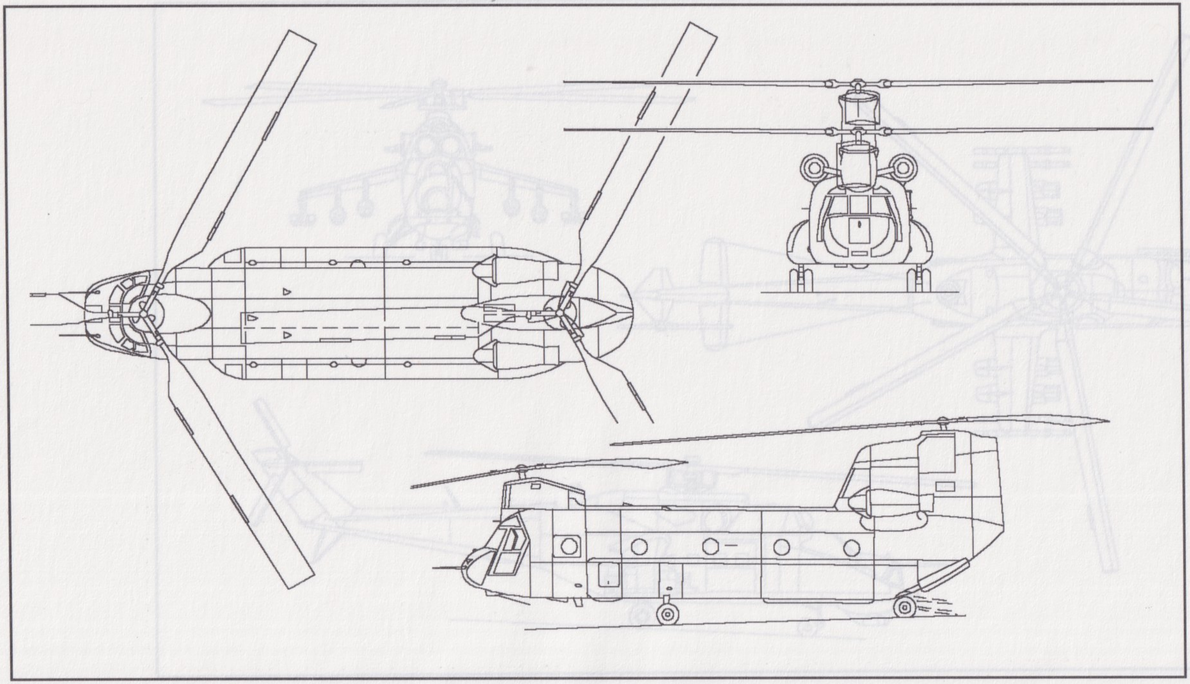


AH-64 Apache

Category:	helicopter gunship	
Origin:	USA	
Main rotor diameter:	48ft 0in	(14.63m)
Length:	58ft 3in	(17.76m)
Height:	15ft 3in	(4.66m)
Max. T-O weight,	21,000lb	(9,525kg)
Max. level speed sea level		160kts
Radius of action	260nm	
g limit	+3.5	

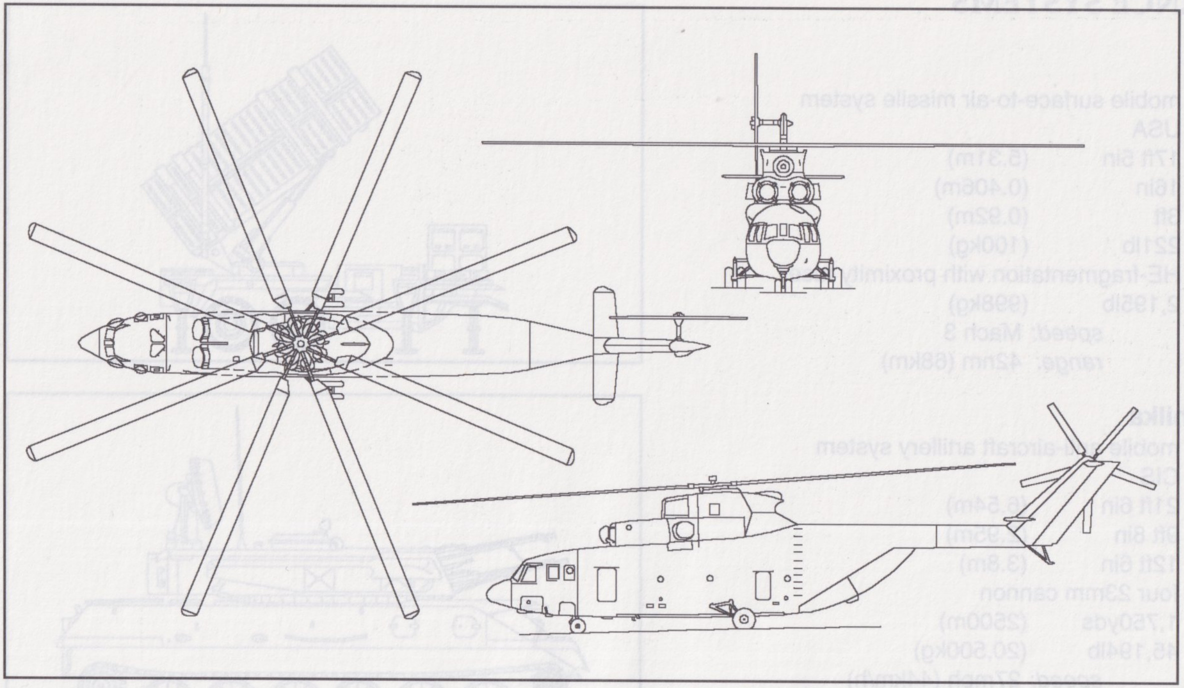


Mi-24 Hind		
Category:	helicopter gunship	
Origin:	CIS	
Main rotor diameter:	56ft 9in	(17.3m)
Length:	70ft 6in	(21.5m)
Height:	21ft 4in	(6.5m)
Normal T-O weight,	26,455lb	(12,000kg)
Max. level speed sea level		172kts
Radius of action	86nm	



CH-47 Chinook

Category:	medium transport helicopter	
Origin:	USA	
Main rotor diameter:	60ft 0in	(18.29m)
Length:	98ft 11in	(30.14m)
Height:	18ft 8in	(5.68m)
Max. T-O weight,	54,000lb	(24,494kg)
Max. level speed sea level		163kts
Radius of action	100nm	

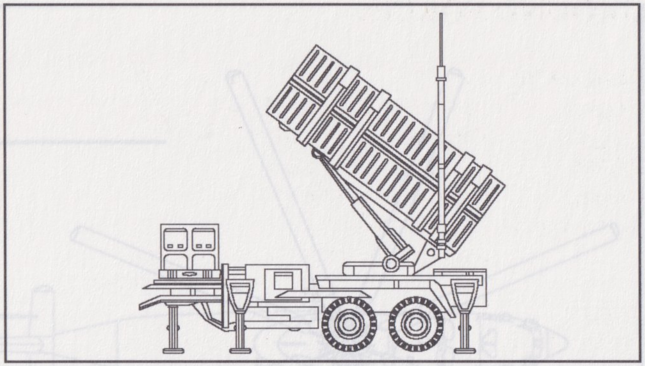


Mi-26 Halo

Category:	heavy transport helicopter	
Origin:	CIS	
Main rotor diameter:	105ft 0in	(32.0m)
Length:	131ft 4in	(40.0m)
Height:	26ft 9in	(8.1m)
Max. T-O weight,	123,450lb	(56,113kg)
Max. level speed sea level		159kts
Radius of action	432nm	

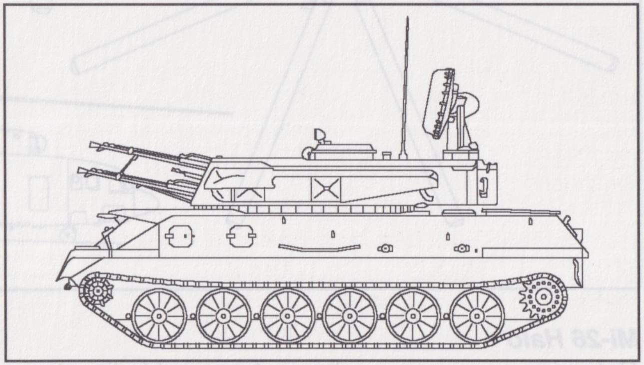
AIR DEFENCE SYSTEMS

Patriot



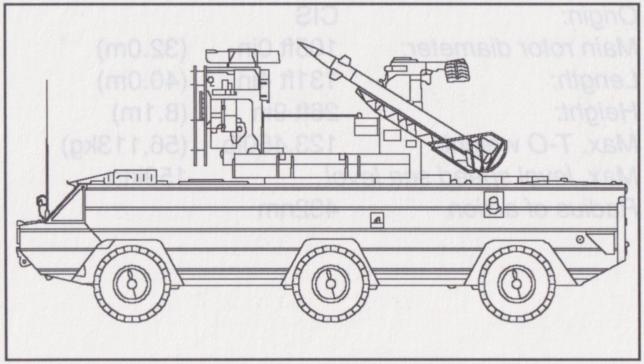
Category:	mobile surface-to-air missile system	
Origin:	USA	
Length:	17ft 5in	(5.31m)
Diameter	16in	(0.406m)
Wingspan:	3ft	(0.92m)
Warhead:	221lb	(100kg)
	HE-fragmentation with proximity fuse	
Weight:	2,195lb	(998kg)
Performance:	*speed:* Mach 3	
	range: 42nm (68km)	

ZSU-23-4 Shilka



Category:	mobile anti-aircraft artillery system	
Origin:	CIS	
Length:	21ft 6in	(6.54m)
Width:	9ft 8in	(2.95m)
Height:	12ft 6in	(3.8m)
Armament:	four 23mm cannon	
range:	1,750yds	(2500m)
Weight:	45,194lb	(20,500kg)
Performance:	*speed:* 27mph (44km/h)	
	range: 280nm (450km)	

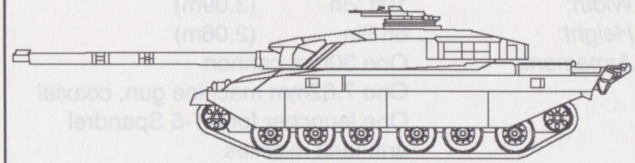
ZRK ROMB (SA-8)



Category:	amphibious mobile surface-to-air missile system	
Origin:	CIS	
Length:	30ft 0in	(9.14m)
Width:	9ft 6in	(2.9m)
Height:	13ft 9in	(4.2m)
Armament:	six SA-8 'Gecko' missiles	
Effective range:	7.5nm	(12,000m)
Altitude limits:	(5,000m)	
Weight:	19,841lb	(9,000kg)
Performance:	*speed:* 37mph (60km/h)	

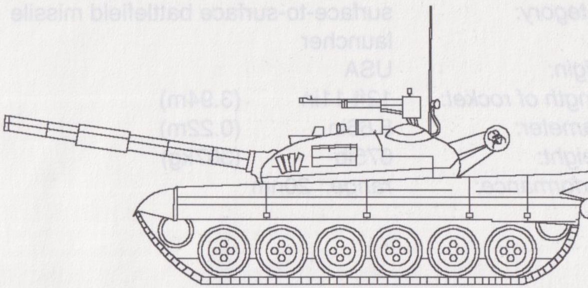
Challenger

Origin:	United Kingdom	
Length:	37ft 11in	(11.56m)
Width:	11ft 6in	(3.52m)
Height:	9ft 8in	(2.95m)
Armament:	one 120mm gun one 7.62mm machine gun, coaxial one 7.62mm machine gun, anti-aircraft	
Weight:	136,685lb	(62,000kg)
Performance:	*speed:* 35mph (56km/h) *range:* 373nm (600km)	



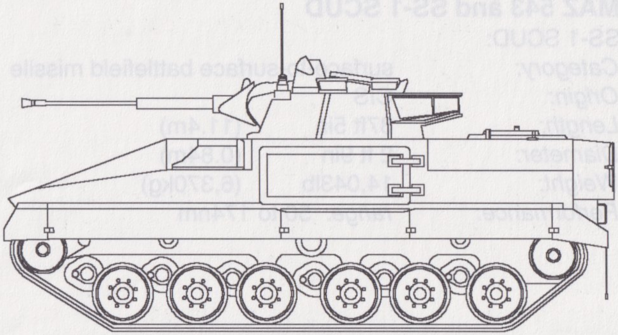
T-80

Origin:	CIS	
Length:	32ft 6in	(9.9m)
Width:	11ft 2in	(3.4m)
Height:	7ft 3in	(2.2m)
Armament:	One 125mm gun One 7.62mm machine gun, coaxial One 12.7mm machine gun, anti-aircraft	
Weight:	94798lb	(43,000kg)
Performance:	*speed:* 46mph (75km/h) *range:* 248nm (400km)	



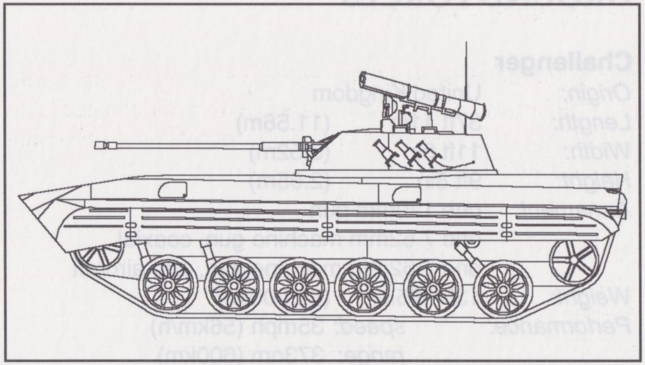
Warrior

Origin:	United Kingdom	
Length:	20ft 10in	(6.34m)
Width:	9ft 11in	(3.03m)
Height:	9ft 0in	(2.73m)
Armament:	One 30mm RARDEN cannon One 7.62mm machine gun, coaxial	
Weight:	49,603lb	(22,500kg)
Performance:	*speed:* 46mph (75km/h) *range:* 310nm (500km)	



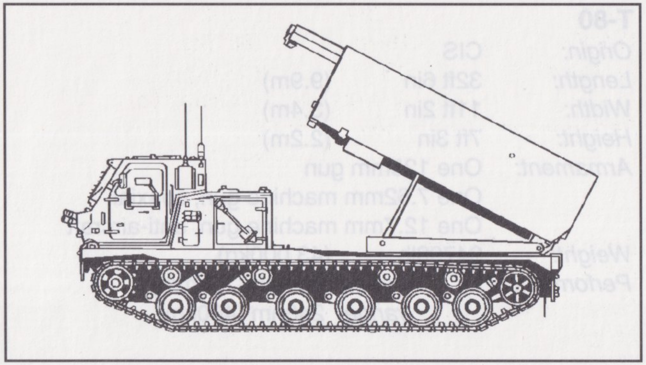
BMP-2

Origin:	CIS	
Length:	22ft 0in	(6.71m)
Width:	10ft 2in	(3.09m)
Height:	6ft 9in	(2.06m)
Armament:	One 30mm cannon One 7.62mm machine gun, coaxial One launcher for AT-5 Spandrel anti-tank missiles	
Weight:	32,187lb	(14,600kg)
Performance:	*speed:* 40mph (65km/h) *range:* 373nm (600km)	



MLRS

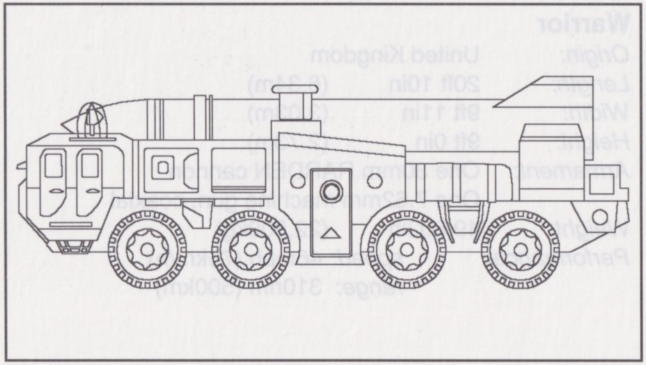
Category:	surface-to-surface battlefield missile launcher	
Origin:	USA	
Length of rocket:	12ft 11in	(3.94m)
Diameter:	8.66in	(0.22m)
Weight:	675lb	(307kg)
Performance:	*range:* 20nm	



MAZ 543 and SS-1 SCUD

SS-1 SCUD:

Category:	surface-to-surface battlefield missile	
Origin:	CIS	
Length:	37ft 5in	(11.4m)
Diameter:	2 ft 9in	(0.84m)
Weight:	14,043lb	(6,370kg)
Performance:	*range:* 50 to 174nm	



WEAPON DATA

The following data has been compiled from manufacturers' information and actual performance may differ considerably. The effective range of all missiles decreases significantly when used at low altitude.

AIM9-L Sidewinder

Origin:	USA	
Guidance system:	all-aspect infra-red	
Length:	9ft 4in	(2.85m)
Diameter:	5in	(127mm)
Span:	2ft 1in	(630mm)
Weight:	188lb	(85.3kg)
Warhead:	25lb	(11.4kg)
	annular blast fragmentation	
Performance:	*speed:* Mach 2.5	
	range: 11nm (17.7km)	

Active Sky Flash

Origin:	United Kingdom	
Guidance system:	all-aspect active radar	
Length:	12ft 1in	(3.68m)
Diameter:	8in	(0.2m)
Span:	3ft 4in	(1.02m)
Weight:	425lb	(193kg)
Warhead:	66lb	(29.9kg)
	proximity and impact delay-fused blast fragmentation	
Performance:	*speed:* Mach 4	
	range: 31nm (50km)	

AA-2-2C Advanced Atoll

Origin:	CIS	
Guidance system:	rear-aspect infra-red	
Length:	9ft 2in	(2.8m)
Diameter:	4.7in	(0.12m)
Span:	1ft 9in	(0.53m)
Weight:	154lb	(70kg)
Warhead:	13lb	(6kg)
	impact delay-fused blast fragmentation	
Performance:	*speed:* Mach 2.5	
	range: 5nm (8km)	

AA-7B Apex

Origin:	CIS	
Guidance system:	semi-active active radar	
Length:	15ft 1in	(4.6m)
Diameter:	8.8in	(0.223m)
Span:	3ft 5in	(1.05m)
Weight:	705lb	(320kg)
Warhead:	88lb	(40kg)
	proximity and impact-fused blast fragmentation	
Performance:	*speed:* Mach 3.5	
	range: 34nm (55km)	

AA-8A/B Aphid

Origin:	CIS		
Guidance system:	infra-red (AA-8A) or semi-active radar homing (AA-8B)		
Length:	AA-8A	7ft 0in	(2.15m)
	AA-8B	7ft 8in	(2.35m)
Diameter:		4.7in	(0.12m)
Span:		1ft 3in	(0.4m)
Weight:	AA-8A	121lb	(55kg)
	AA-8B	132lb	(60kg)
Warhead:	proximity and impact-fused blast fragmentation		
Performance:	*speed:* Mach 3		
	range: AA-8A	6 nm	(10km)
	AA-8B	9nm	(15km)

AA-10 Alamo

Origin:	CIS		
Guidance system:	infra-red or semi-active radar homing		
Length:	radar variant	13ft 1in	(4.0m)
	IR variant	10ft 6in	(3.2m)
Diameter:	7.3in	(0.185m)	
Span:	2ft 9in	(0.855m)	
Weight:	radar variant	440lb	(200kg)
	IR variant	342lb	(155kg)
Warhead:	blast fragmentation		
Performance:	*speed:* Mach 3		
	range: radar variant	24nm	(40km)
	IR variant	12nm	(20km)

Air-to-ground weapons

BAe/ Marconi ALARM

Origin:	United Kingdom	
Category:	air-to-surface anti-radiation tactical missile	
Guidance system:	passive radar seeking	
Length:	13ft 11in	(4.242m)
Diameter:	8.7in	(0.22m)
Span:	2ft 4in	(0.72m)
Weight:	385lb	(175kg)
Warhead:	laser proximity-fused MBB HE	
Performance:	*speed:* classified	
	range: classified	

JP 233

Origin:	United Kingdom	
Category:	heavy-weight airfield attack and area-denial submunition dispenser	
Guidance system:	computer-controlled weapon release	
Length:	21ft 6in	(6.55m)
Width:	2ft 9in	(0.84m)
Height:	1ft 11in	(0.6m)
Weight:	5,148lb	(2,335kg)
	per dispenser (Tornado carries 2)	
Warhead:	30 SG357 concrete-penetrating and 215 HB876 area-denial submunitions	

BL755

Origin: United Kingdom
Category: medium-weight cluster bomb
Method of release: lay down or manual
Length: 8ft 0in (2.45m)
Diameter: 1ft 4in (0.42m)
Span: 1ft 10in (0.56m)
Weight: 582lb (264kg)
Warhead: 147 anti-tank/fragmentation bomblets

1000 lb freefall bomb

Origin: United Kingdom
Available in three varieties:
(a) general purpose (GPB)
(b) retarded (RET)
(c) laser-guided (LGB)

Method of release:
(a) GPB - manual, loft or lay down
(b) RET - manual or lay down
(c) LGB - manual, loft, lay down or using TIALD

GLOSSARY AND ABBREVIATIONS

AA threats	anti-aircraft threats e.g. AAA and SAM sites
AAA	anti-aircraft artillery
AAM	air-to-air missile
ACM	air combat manoeuvering
ACQR	acquire through autopilot
ADI	attitude direction indicator
ADV	air defence variant of Tornado
AFDS	autopilot and flight director system
AFV	armoured fighting vehicle
AHA	altitude/heading acquire mode of autopilot
AIM9-L	heat-seeking air-to-air missile
ALARM	air-launched anti-radiation missile
Alpha	see angle of attack
ALT	altitude
Analogue joystick	joystick with output proportional to its displacement
Angle of attack	angle between wing and direction of airflow
Approach point	start of approach to an airfield
APRCH	approach
AUTO	under total autopilot control
Autothrottle	system used to set a demanded airspeed
Autotrim	computer-assisted turn coordination
AGM	air-to-ground missile
ALARM	air-launched anti-radiation missile
ALT	altitude
AOA	angle of attack
AWACS	airborne warning and control system
B risk	terrain following system safety margin error warning
Bearing	heading required to fly towards target or waypoint
Blackout	loss of consciousness due to pulling g
BL755	cluster bomb
BVR	beyond visual range
C3	command, control and communications
CAP	combat air patrol

CAS	close air support
CCIP	continuously computed impact point
Chaff	tiny foil strips used to decoy radar-guided missiles
CIS	Confederation of Independant States
Combat power	maximum reheat setting
Dead stick	flight with zero engine thrust
deg	degree
Digital joystick	joystick capable only of on/off output
DIR	direct - ALARM mode
ECM	electronic countermeasures
Egress	flying out of the target area
EWR	early warning radar
Flaps	trailng edge aerofoils on each wing
Flares	used to decoy heat-seeking missiles
g or G	weight multiplying factor, units of gravity
Glideslope	descent rate reference of ILS system
G-LOC	gravity-induced loss of consciousness
GPB	general purpose bomb
Groundspeed	actual speed over the ground
HAS	hardened aircraft shelter
HDG	heading
Heading strip	symbols on HUD showing aircraft heading
HUD	head up display
IAS	indicated airspeed
IDS	interdictor strike variant of Tornado
IND	indirect - ALARM mode
ILS	instrument landing system
Initial point	turning point from which you start your attack run
Jettison	to reduce aircraft weight in an emergency
JP.233	runway denial weapon
KIA	killed in action
KIT	killed in training
kts	knots, nautical miles per hour
LAY	laydown attack
LFT	loft attack

REFERENCE

LGB	laser-guided bomb
Lift vector	force generated by air flowing over the wings
Localiser	left/right reference of ILS system
Mach number	aircraft speed expressed as a fraction or multiple of the local speed of sound
MAN	manual control or manual attack
MFD	multi function display
MTOW	maximum takeoff weight
n.m.	nautical mile
NLT	not later than
OCU	operational conversion unit
Package	group of weapons designated for use against a particular target
Pitch bars	lines drawn on HUD showing aircraft pitch and roll
PLN	flight plan tab display
POL	petrol, oil and lubricants
POW	prisoner of war
RAF	Royal Air Force
Redout	loss of consciousness due to negative g
RET	retarded bomb
Ride height	altitude setting selected when using terrain following
RPM	engine revolutions per minute, corresponds to thrust if reheat not selected
RWR	radar warning receiver
SAM	surface to air missile
SARH	semi active radar homing
Sec	second
SKYF	HUD symbol for Sky Flash missile
Sky Flash	radar-guided air-to-air missile
Slats	leading edge aerofoils
SMD	stores management display
SPILS	spin prevention and incidence limiting system
Spin	stalled descent along a steep helical path
Stall	loss of control due to wings no longer generating lift
Tab	multi-purpose displays in rear cockpit

TAS	true airspeed
Tasking order	mission description
TEL	time early/late
TF	terrain following
TFR	terrain following radar
THROT	autothrottle
Thrust reversers	devices used to achieve a braking effect
TIALD	thermal imaging and laser designating system
ToO	target of opportunity
TOT	time on target
Training area	flying area used in simulator or flying training
TRN	terrain referenced navigation
True airspeed	speed relative to the air through which you are flying
TTG	time to go
TV TAB	large multi-purpose displays in the rear cockpit
TWCU	Tornado Weapons Conversion Unit
Unloading	pushing the stick to reduce aerodynamic drag
VSI	vertical speed indicator
War zone	combat flying area - choice of 3
Waypoint	map position stored by the navigation system

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Suggested reading

Panavia Tornado	Dr. Alfred Price
Fighter Combat	Robert L Shaw
The Ace Factor	Mike Spick

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